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ORIGINAL ARTICLES.

The Superficial Deposits near Sunderland and the Quaternary Sequence in E. Durham.

By George Coupland and the late David Woolacott, D.Sc., F.G.S.

(Plate I.)

In this paper it is proposed (1) to describe the superficial deposits along the coast between Sunderland and Ryhope, (2) to give a short account of the beds exposed in the recent excavations at the Sunderland Barracks, and (3) to attempt a correlation of the Glacial and Post-Glacial deposits of the East of Durham. It is felt by the authors that a true conception of the sequence of events during the Pleistocene and Recent periods will be eventually obtained by the examination of typical areas and by the working out of the succession and mode of origin of the deposits in such regions.

The east coast of Durham is especially interesting because of the complex nature of the superficial strata that occur along it. While it is difficult to be certain of the mode of origin of some of them, yet certain facts of importance stand out clearly which are of some interest in connexion with the general subject of Pleistocene Geology. Along this coastal region there are exposed (*a*) Cromerian beds (not in situ), (*b*) Scandinavian shelly drift, (*c*) Loess, (*d*) the *moraine profonde* of the British ice-sheet, (*e*) Fluvio-glacial deposits, Kaims, etc., (*f*) Raised Beaches, (*g*) Submerged Forests, etc.

The Section between Sunderland and Ryhope.

The detailed examination of this was done mainly by Mr. Coupland, but the authors are also indebted to Mr. E. Merrick, M.Sc., F.G.S., who examined the section and placed at their disposal his detailed knowledge of the superficial deposits, obtained in the continued study of them in the Tyne region. The section is about 3 miles long, varying in height from about 40 to slightly over 100 feet. It is entirely composed of Magnesian Limestone and superficial deposits. The limestones consist of the Middle Dolomitic, the Flexible, and the Upper Concretionary series. The north part of it consists of an anticline of these rocks cut off abruptly on the south by a thrust plane, which can be clearly seen in the cliff, about 300 yards to the north of Salterfen Rocks. Southwards the bed rocks belong to the bedded, dolomitic, often highly brecciated, limestones of the Middle division. The Permian of the north part of this coast is described and illustrated in Dr. Woolacott's paper on the Stratigraphy and Tectonics of the Permian of Durham (Northern Area).[1] Near Ryhope Dene there was at one time exposed an infilling of a fissure with red and green marl, which may have been derived from marly beds of Upper Magnesian Limestone age that once overlaid the area. The superficial deposits of this coast are usually referred to as Glacial, and often in a general way stated to be boulder clay, yet it is a peculiar feature of the section that by far the greater proportion of the deposits is sand and gravel, true boulder clay in reality forming only a small part of the beds.

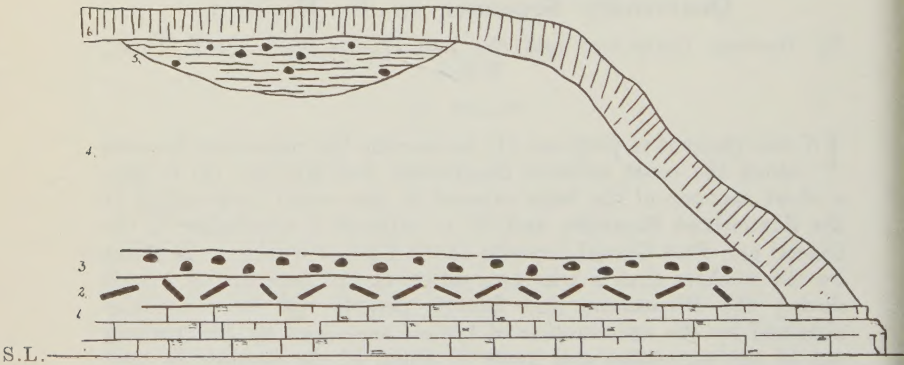

FIG. 1.—Section along the cliff on the south side of the promontory at Salterfen Rocks. The beds seen are: (1) Middle Magnesian Limestone; (2) Basal Breccia; (3) Main Boulder Clay (Scarp); (4) Sand bed; (5) Saucer-shaped mass of sand, gravel, and clay; (6) Columnar clay (Brown clay). One of the distinct features of the section is the manner in which the Brown clay overlaps the other deposits. There had apparently been extensive denudation of the other superficial deposits before it was laid down. S.L. = Sea-level. Height of cliff about 75 feet.

Definite glacial smoothing and polishing have been observed at several places on the bed rock, and at Salterfen Rocks well-marked striations running S. 17° E. are sometimes exposed. Intermittently overlying the limestone is a basal breccia, consisting of fragments and sheet-like masses of the bed rock set in a matrix of powdered limestone. It seems clear that the limestone dust has been produced by the actual grinding of the surface of the rock and the pieces by the shearing off of the upper layers of it by the pressure of the moving ice-sheet. While the evidence for this shearing is seen almost continuously along the exposure, it can be most distinctly observed to the north of Salterfen, where a specially interesting section occurs, showing the thrusting off of large sheets of the limestone, several feet in length—a more definite proof of the passage of land ice over the area could not be required[1] (Pl. I and Fig. 1). The ice would appear to have been British ice moving southwards parallel to the coast, being pressed in this direction by the Scandinavian mass. The basal breccia and the overlying Main Boulder Clay or Scarp represent the *moraine profonde* formed by it. The thickness of the limestone breccia varies up to 6 feet, but its surface is generally parallel to that of the limestone, probably showing the constant and uniform pressure of the ice during its production. Both the upper and lower surfaces are occasionally smoothed, it would thus seem that the clay above has moved at a slightly greater rate than this basal breccia, which has been retarded by the friction of the limestone surface. By far the greater proportion of the boulders are fragments of the underlying limestone, but small travelled erratics occasionally occur in it.

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[1] *Univ. Durham Phil. Soc.*, vol. iv, pl. v (1911–12), fig. 9, p. 266, and fig. 10, p. 288.

Above this basal breccia there is an almost continuous layer of a stiff brown clay full of fragments of local rocks and of travelled erratics. It reaches a thickness of 30 feet, and where well developed it can be divided into two parts. The lower is a typical till, massive, stiff and unbedded, and is the clay that has been called by Trechmann and Woolacott the Main Boulder Clay, and corresponds to the true "Scarp" or unworkable stony clay of the Newcastle Brickfields (Merrick). The upper is distinguished by showing traces of bedding, especially when dried corresponding to the more stony variety of the Newcastle Black Clay.[2] The boulders in both clays are often striated and polished, but angular, sub-angular, and rounded stones occur in them. The most typical glaciated boulders are of Carboniferous Limestone, but pieces of the Volcanic Series of Borrowdale, granite, Whin Sill, etc., are common. Cheviot rocks are extremely rare. The Scarp portion of this deposit is the *moraine*

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[1] The masses of limestone can be seen in all stages of shearing. Sand and gravel in places have been let in to fill up the fissures formed beneath the partly sheared off masses.

[2] The Scarp may be regarded as typical stony boulder clay. It shows no traces of bedding on drying, is charged with grit, and contains many boulders, a large proportion of which are usually limestone. The last feature renders it of no commercial value. The Black Clay is also a stony clay, but shows traces of bedding when dried. It is not gritty, being worked in the fingers and cutting like butter. It has an irregular fracture. It usually contains less stones than the "scarp" and resembles the comparatively stoneless blue and leafy clays which are used for brickmaking. For the properties of these clays and their succession the reader is referred to Merrick's paper on the "Superficial Deposits around Newcastle": *Proc. Univ. Durham Phil. Soc.*, vol. iii, pl. iii, 1908–9, p. 141.

profonde of the ice that moved parallel to the coast during the epoch of maximum British glaciation. The Western ice had reached the east coastal region first, and was afterwards pressed southwards by the Northern ice, hence the mixture of Lake District, Cheviot and other rocks.

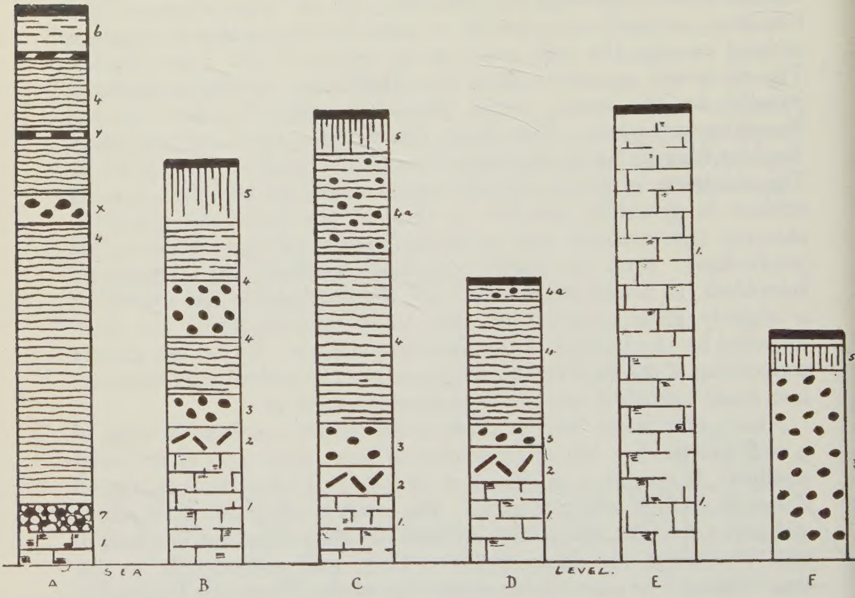

Fig. 2.—Sections from south to north at points along the coast to show the variation in the deposits. A, 102 feet contour; B, South of Salterfen; C, Salterfen Rocks; D, Nanny Rain's Springs; E, The Crags; F, Hendon. 1, Magnesian Limestone; 2, Basal Breccia; 3, Main Boulder Clay; 4, Bed of sand with masses and beds of clay; 4*a*, One of the saucer-shaped depressions of sand, gravel, and clay; 5, Columnar or Brown Clay; 6, Red Sandy soil. B and C may be taken as typical sections of the coast, showing the Basal Breccia, Main Boulder Clay, Sand bed with Clay inclusions, or gravel-filled troughs overlaid by Columnar or Brown Clay. At A the Basal Breccia and Main Boulder Clay are absent, having been apparently denuded. Resting on the rock surface is a bed of conglomerate (7), and nearly the whole of the cliff is formed by sand with clay and gravel inclusions. At X beds of laminated clay occur, at Y pieces of Cheviot rocks are specially noticeable boulders in the clay. In the gravel beneath 6 the flints of the higher level were found, and in the sand beneath 5 in B those of the lower level. The sections are from the base of the cliff—the height of the highest being 102 ft. above sea-level.

The upper portion, or Black Clay type of deposit, with its traces of bedding and more plastic and less gritty nature, is, however, probably not true *moraine profonde*, but derived from material that was being carried in the ice—en-glacial—and deposited when it melted. The whole mass of these two clays is extremely hard, frequently shows vertical jointing and often stands out like buttresses on the coast. On drying, the vertical face cracks and commonly shows small reticulations. The average size of the contained boulders is about 9 inches, larger blocks being scarce, but here and there large boulders up to 4 feet in length rest on its surface beneath the succeeding sands and loams. As small rolled masses of clay occur in these latter beds it would appear that a large portion of this clay has been denuded and these blocks left as a residuum. That much denudation of the clay and basal breccia has taken place is also evident, because at one part of the section the whole of these lower beds have been removed and the bed rock is overlain by a coarse conglomerate, above which is the thick bed of sand (Fig. 2, A). The base of the Main Boulder Clay resting on the basal breccia is often smooth, showing that there has been relative movement between these beds under the moving ice.

Resting unconformably on these clays is a deposit of mixed sand and mud, which stains the fingers brown. It probably represents an abnormal thickening of the "Rotten Loam Sand" of the Newcastle district formed by the denudation of the underlying clays by running water and the infilling of the trough so produced. If it is the Rotten Loam Sand, then the "Rag" and "Common Clay" of the Newcastle district appear to be absent. It is impossible to say whether they were deposited in this area and subsequently removed before the sand was laid down, but it is significant that clays of these types do occur in the Barracks section, which is described later. This bed of sand is the thickest and most continuous deposit along the coast, reaching a maximum thickness of 80 feet. Bands of clay containing water-worn stones occur in it, but where the clay is absent the sand is stoneless. As already stated, small rolled pieces of stony clay occur in it, while large isolated masses of the less stony variety of the Newcastle Black Clay are found more or less irregular in form, tapering off at the ends and up to about 100 tons in weight. The sand is usually regularly bedded, but current bedding is noticed in places. Contortions are at times observed in it, especially near the edges of the contained masses of Black Clay—indeed, the occurrence of these and the contortions appear to be, in the main, associated phenomena. It is important to notice that the sands are not contorted or disturbed on a large scale. It would appear impossible that a sheet of land-ice can have passed over the area since they were laid down. The authors have endeavoured to arrive at some idea of its mode of origin, but admit it is difficult to get one that is satisfactory. The sand is unfossiliferous. That it does not represent a "Middle Sand and Gravel deposit" seems certain, i.e. it is not an Interglacial or Interval deposit. The material forming it would, however, seem to have been produced partly by the denudation of the pre-existing boulder clays and partly by detritus from melting ice. It may in reality be an estuarine or marine deposit formed at the end of the Glacial period, when the coastal region was embayed and enormous quantities of sand and mud would be carried down by streams from the melting glaciers, the masses of Black Clay and associated contortions being produced by rafted material dumped down from melting icebergs.

The level surface of the sand is frequently interrupted by masses of sand, clay, gravel and boulders, which appear to occupy saucer-shaped denuded hollows, the longest being 80 yards. The sand in these semi-circular troughs is often contorted. These masses occur at the top of the cliff at intervals along the coast. Many of the stones occurring in them are weathered and cracked along the bedding planes. It is remarkable that these upper beds contain a larger proportion of Cheviot rocks (10–20 per cent) than the lower clays. This is in accordance with the view that the Lake District-Galloway ice retreated from eastern Northumberland and Durham before the Tweed-Cheviot ice.[1] These troughs filled with fragmental material are difficult to explain, but that they were formed by denudation and subsequently filled by deposits from torrential waters seems certain, and most probably they were formed during the uplift of the coastal region that produced the raised beaches. It appears to the authors to be impossible to determine whether any extensive removal of any thickness of these sands or of the saucer-shaped deposits has taken place before the Brown clay was deposited on them, but that they had been extensively removed along the coastal border before this clay was deposited seems certain. The Brown clay to be described later was deposited on the denuded edges of these sands from the top to the base of the cliff at Salterfen (see Section, Fig. 1).

Between Ryhope and Ryhope Dene four exposures occur of a bed of cemented gravel (usually called cemented drift) about 6 inches thick. It rests on a level platform. A similar deposit occurs at about the same level (60 feet) at Easington,[2] associated with the raised beach there, and it can be traced up the coast, lying on a horizontal beach of bed-rock or clay. Although no marine shells have been found in this deposit in the Ryhope area, there can be no doubt that it is the same deposit and of the same origin as the Easington Deposit. In this area also the cemented drift passes up into a deposit of large water-worn fragments of Magnesian Limestone, which reaches a thickness of 30 feet. The limestone pebbles are from the Bryozoa Reef, about 1 mile to the west. This is apparently the same as the bed of boulders that is exposed in Bell's gravel-pit (noticed in the next paragraph). It would appear to be definitely connected with the Raised Beaches, and to have been washed down to the then existing sea-margin by torrential waters.

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[1] See Smythe, *Glacial Geol. of Northumberland*, 1912, and Woolacott, Geol. Mag., Vol. LVIII, 1921, p. 29.

[2] "On the 60 ft. Raised Beach at Easington, Co. Durham": Geol. Mag., Vol. LIX, 1922, p. 64.

About 400 yards from the coast an excavation for gravel and sand has been made at Ryhope, and in it an interesting section is exposed. The following table shows the sequence of the deposits.

Deposits in Bell's Excavation, Ryhope.

1. Well-bedded, beach-like deposits, 12 feet in thickness, similar to the beds of the Raised Beaches of Easington, Cleadon, and Fulwell. The sands and gravels are current-bedded and perfect ripple-marking occurs at one horizon. Fragments of *Littorina* and *Cyprina* occur. The line of the Raised Beaches may be safely traced from Easington through Ryhope to the gravels and sands of the Fulwell Hills.
2. Sandy, laminated clay—locally developed up to 2 feet.
3. Sands, often highly contorted (with masses of clay).
4. Very coarse deposit of water-worn fragments of Magnesian Limestone up to 10 feet thick. This would appear to be the same deposit as that noticed on the coast in the last paragraph, and if the correlation of these deposits is correct, then in the authors' opinion the lower raised beaches at Easington and Ryhope are earlier than the higher Raised beaches in this gravel-pit and Fulwell, Cleadon and Marsden. One of the marked features of these deposits is the presence of rolled flints in them.

Later than all these deposits, and resting unconformably on them, is a deposit of Brown Columnar or Prismatic Clay, recognized by a tendency to weather into vertical columns about 4 feet long and 5 or 6 inches across. It probably represents both the Brown Clay and the Yellow Clay of the Newcastle district. At Salterfen it could be seen (and can still be seen in part to do so) to run from the top to the base of the cliff, overlapping the saucer-shaped masses of sand, the Main boulder clay, the Basal Breccia on to the rock. This clay occurs almost continuously along the top of the cliff, following the contour of the sand and other deposits, and maintaining an almost uniform thickness. It appears to have run across the deep trench-like denes (of which there are three in the section described) that form such a marked feature of the Durham Coast; if so these denes are of very recent formation, being later than the Raised Beaches, and apparently later than the Brown or Columnar Clay.

This clay is sandy, some of the sand grains being rounded, but it contains small water-worn stones. As it rests on several different deposits without change it would appear that it cannot have been formed by weathering in situ. It is probably a deposit formed by the ordinary processes of denudation, since the final retreat of the ice, in part rain-wash, in part wind-formed, and in part by weathering in situ. It is of interest that the Brown Clay of this type underlies the Yellow, and that they do not appear to pass gradually into one another. The Brown may have been produced during the dry steppe-like conditions that occurred at the end of the Pleistocene, the Yellow under the wetter conditions that followed. It is perhaps worthy of emphasis that in these deposits there would seem to be evidence of two distinct unconformities, periods in which considerable denudation of the underlying beds took place, the first beneath the bed of sand which rests on a denuded surface of the lower clays, the second beneath the Columnar Brown Clay which we have seen may rest on the edges of all the other deposits. There is also a minor unconformity between the bed of sand and the saucer-shaped depression. Another point of interest which is referred to more particularly in the Barracks section is the fact that although the beds are most irregular in thickness yet there is a definite succession of them.

Above the Columnar Clay there occurs at one part of the section a blown sand containing numerous shell fragments, and at the highest part of it (102 O.D.) there is a deposit of red, sandy soil 5 feet in thickness.

Flints in the Deposits.

Unworked flints occur in the Scandinavian Drift at Warren House Gill, near Castle Eden Dene, and in a comparatively stoneless clay at the Trow Rocks, South Shields (Howse's so-called Scandinavian Drift). The authors have not observed flint in the Basal Breccia, Scarp, or the Black Clay in the section under discussion, but it occurs in the gravels of the Raised Beaches at Easington, Ryhope and Cleadon.

Definitely worked flints have been obtained from a level 5 feet below ground at the point where the cliffs reach their greatest height in this section. About 400 pieces were found in an area of a few square yards. These pieces are mostly small, irregular broken bits, long flakes, and minute chippings Some of the pieces have been cracked by fire and a few of the long flakes show usage on one edge. A " triangle ", possibly referable to the Tardenoisian Culture, at present being investigated by Mr. Coupland, was also found on this site. With the exception of one or two pink pieces, all the flint is of a blue-grey variety ; both varieties can be found in the deposits forming the raised beaches.

At a lower level, beneath the Brown Clay and just covered by the ripple-marked sand, four pieces of flint were found by Messrs. Merrick and Coupland. In the opinion of all who have seen these pieces, one at least has been subjected to human usage. Although Mr. Coupland does not insist on this point, the presence of flint at this level in an otherwise stoneless sand, is very interesting. None of the pieces shows any signs of having been rolled far. If these pieces can be accepted as having been used by human beings it would place man in Durham before the formation of the Columnar or Brown Clay.

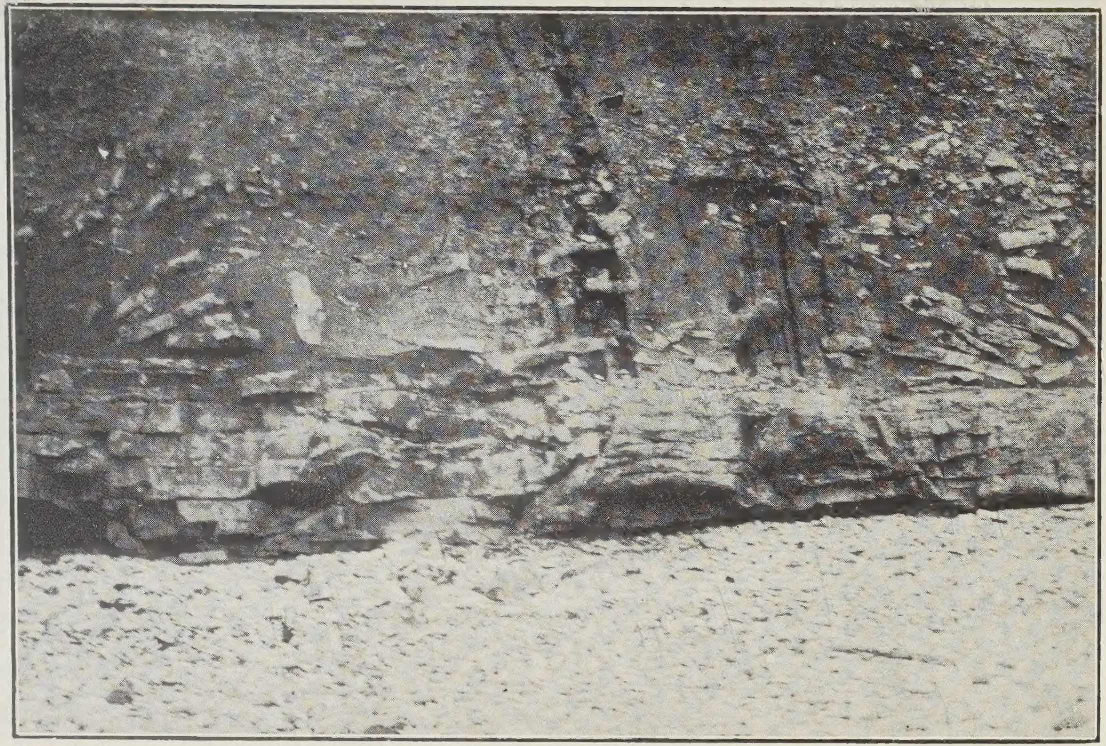

Photo G. C.

Photograph of Cliff about 200 Yards North of Salterfen Rocks, showing sheared-off sheets of limestone in the Basal Breccia with the Scarp or Main Boulder Clay above. The height of the cliff exposed is 20 feet. N.B.—The dark vertical streaks are made by running water.—G. C.

[To face p. 8.

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The Section at the Barracks, Sunderland.

During excavations (1923–4) at the Barracks, South Dock, Sunderland, there was exposed a very interesting section of the superficial deposits, of which, as they will be eventually completely covered up, a record should be preserved. The section lies about half a mile to the north of that along the coast which has just been described. The change in the short distance is remarkable: the thick sand bed has almost tapered out, being represented by sandy clay, and there is a more complete succession of the clays, the Rag and Common Clay being well developed, although absent in the coastal section. The sequence is the same as in the Tyne valley. This succession, in the opinion of Merrick and the authors, is the most peculiar feature of the Pleistocene and Recent beds in the coastal region of the Tyne, Wear, and Tees. Dr. Woolacott regards it as due in the main to the changes of level in this region (at any rate changes in relative height of land and sea) since the beginning of the Glacial Period, combined with the retreat and regrowth of the ice-sheets that took place. The beds vary in thickness from point to point, and any one, or all, may be absent, yet the order of succession is always the same. It is not proposed in this paper to describe the deposits in detail, but to place on record the fact that the succession exposed in these excavations was in the same order as that which occurs in the Tyne valley, so that this sequence may be brought before the notice of geologists and tested by future workers. The different clays, the names of which as used by the brickmakers of the Newcastle and Birtley districts were adopted by Merrick in his study of the Tyne region,[1] can be identified by certain properties.

Correlation of the Deposits.[2]

It is of interest to attempt a general correlation of the deposits here described with those described by Trechmann in the south of the county, together with the series in the Tyne valley worked out by Merrick, and to consider them all in relation to the general classification of the Pleistocene and Recent deposits. Much information is tabulated below without attempting to state the proofs for the position of certain beds, etc., in the sequence. The correlation is of value as representing a considered opinion by one who has seen at various times all the deposits. The Pleistocene period is considered to be one continuous epoch with ice always probably occupying the main gathering grounds. The so-called Interglacial Periods are regarded as times of ice retreat producing long intervals in the glaciation and freeing from ice considerable areas, but never the main centres of dispersion. If the term "Interglacial" is used in this way there is no objection to it. The

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[1] "Superficial Deposits around Newcastle": *Proc. Univ. Durham Phil. Soc.*, vol. iii, pl. iii, 1908–9, p. 141.

[2] By Dr. Woolacott.

GENERAL SUCCESSION OF DEPOSITS AT THE SUNDERLAND BARRACKS AND IN THE TYNE VALLEY.

Sunderland Barracks.				Tyne Valley.
		Ft.	in.	
Recent Surface Deposits.	Made ground Sand (rounded grains, shells) Made ground Brown sand Soil.	0 1 1 1	8 0 0 6	Soil.
Yellow Clay.	Stoneless	6	0	Yellow Clay.
Brown Clay.	Sandy at base			Brown Clay. Rotten Loam. Sand.
Common Clay.	A brown stony clay, bluish on fracture passing up into a coarse leafy clay. Full of roots which stop at the upper surface[1]	5	0	Common Clay.
Rag.	A tough clay with irregular fracture, upper part bedded but passing down into unbedded stony clay with large and small boulders, some glaciated (bed of gravel at base)[2]	10	0	Rag.
Chocolate Clay.				Surface Leafy.
Black Clay.	Stony clay with striated and unstriated boulders, many minute stones, cuts like butter. Traces of bedding on drying	7	0	Black Clay.
—	—	—		Bottom Leafy.
Scarp.	Typical stiff unbedded boulder clay. Till. Base not seen but bed rock not far below	7	0	Scarp.
—	—	—		Bed of Sand.[3]

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[1] The Common Clay was full of roots which stop at the upper surface. The top of this clay must have been a land surface or swamp shortly after its deposition.

[2] The surface of the Rag was in one part of the section covered with large boulders, which stood out above the clay surface when the overlying sandy brown clay had been removed. It would appear that denudation of the clays must have taken place at this horizon here in the same manner as in the coastal section.

[3] This bed of sand, gravel, loams, and laminated clay, proved by Merrick to reach a considerable thickness beneath the boulder clay (Scarp) of the Tyne Valley, is not represented on the coast in any section. It is in the opinion of Dr. Woolacott a glacial outwash from the oncoming ice-sheet partially filling up the pre-Glacial Tyne Valley. It contains travelled erratics, and Merrick regards its upper surface as having been glaciated.

writer has already briefly discussed this subject in the GEOLOGICAL MAGAZINE, January, 1921. He regards the Cromerian beds as an Interglacial deposit before the arrival of the Scandinavian ice on the Durham coast. The reassorted deposit at Horsebridge Head, with North Scottish erratics beneath the Main Boulder Clay, is regarded as an Interglacial river-formed deposit in the 2nd Interval, and as affording evidence that Scottish ice had reached Northumberland during the Second or Mindel epoch of glaciation. There is also very definite evidence for this epoch in the loess and in the apparent impossibility of explaining the derived fauna of the Kaims without there having been an Interglacial shore-line during this Interval. During the period of maximum British glaciation (Third) whose *moraine profonde* was the Main Boulder Clay, the Lake District, Galloway or Western ice reached the coast before the Tweed-Cheviot or Northern ice. Trechmann has proved that clay with Lake District erratics is overlain by one with Cheviot and other rocks at Hartlepool and in the Sunderland district Coupland pointed out that the upper beds in the coast section contain a higher percentage of Cheviot rocks than the lower—the western ice is regarded as having reached the coast, and then later the ice streams were all diverted southwards by the pressure of the Scandinavian ice in one epoch, viz. the Riss or III. There does not appear to be any evidence for the reglaciation of the coastal region of Northumberland and Durham after the retreat of the ice at the end of this period, although such beds as the Black and Leafy clays afford evidence of ice still occupying the ground to the west and north (and possibly also the east), and such clays as the Rag and Common clays appear to prove a later regrowth of the ice. It seems impossible that an ice-sheet can have passed over the Leafy clays without disturbing them in any way. The Rag and Common clay may have been deposited under water and are not true boulder clays, although some of the ice-scratched boulders in the Leafy, Rag, and Common clays may have been ice-rafted.

SUGGESTED CORRELATION OF THE GLACIAL DEPOSITS OF EAST DURHAM DISCUSSED IN THIS PAPER.

(BY D. WOOLACOTT.)

In drawing up this table the author desires to record his indebtedness to the work of Howse,[1] Merrick,[2] Trechmann,[3] Smythe.[4]

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[1] Howse, "On the Glaciation of the Counties of Durham and Northumberland": *Trans. N. of Eng. Inst. Min. Eng.*, vol. xiii, 1863–4, p. 169; and *Guide to the Collection of Local Fossils in the Natural History Museum, Newcastle*, 1889.

[2] Merrick, "On the Superficial Deposits around Newcastle-upon-Tyne": *Proc. Univ. of Durham Phil. Soc.*, vol. iii, pl. 3, 1909.

[3] Trechmann, "Scandinavian Drift of the Durham Coast": *Quart. Journ. Geol. Soc.*, vol. lxxi, 1915, pp. 53–82; and "On a Deposit of Interglacial Loess and some Transported Freshwater Clays on the Durham Coast", ibid., vol. lxxv, 1919, pp. 173–203.

[4] Smythe, "Glacial Geology of Northumberland": *Trans. Nat. Hist. Soc. Northumberland*, 1914.

NEOLITHIC.	Yellow Clay Brown Clay Rotten Loam Sand with *Sus scrofa* (Wild Boar) Submerged forests (about this horizon) with *Cervus elaphus* (Red Deer). Raised Beaches (about this horizon) temperate fauna.	The Tyne Silt with *Cervus elaphus*, *Bos primigenius* (Urus),[1] began to fill up the Tyne valley after the uplift that produced the Raised Beaches. According to Merrick the glacial deposits were cut out (down to bed rock in places) by river action and the silt has subsequently filled up this valley. This action would be intensified during the depression that produced the submerged forests.
IV WÜRM.	Probably represented by Rag and Common Clays.[2]	
3rd Interval Riss–Würm.	Probably represented by Bottom Leafy, Black, and Surface Leafy Clays. Remains of *Cervus giganteus* (Irish Deer) and *Elephas primigenius* (Mammoth) have been found, both probably from this horizon.	
III RISS.	Maximum local glaciation. Main Boulder. Clay. Scarp. The Shell-bearing (one Arctic form) Kaims of E. Durham were formed on the edge of the Tweed-Cheviot ice after the retreat of Lake District–Galloway ice.	During this period the Lake - District - Galloway ice reached the coastal region of Northumberland before the Tweed-Cheviot and the latter over-rode the *moraine profonde* of the former producing a clay (Main Boulder Clay or Scarp) with a mixture of erratics, leaving, however, a deposit with a pure culture of the western rocks at Hartlepool which is the *moraine profonde* of the Stainmore-Tees valley glacier.
2nd Interval Mindel-Riss.	Loess and shore-line deposits from which shelly sands and gravels of the Kaims of E. Durham [3] were deposited. Stream deposit at Horsebridge Head.[4]	The thick bed of sand, gravel, loam, and laminated clays at the base of the deposits in the Tyne valley [2] is probably a glacial outwash produced at the beginning of III or even during II.
II MINDEL-SAXONIAN.	Scandinavian shelly drift with several Arctic forms.[3]	
1st Interval Günz-Mindel.	Cromerian Freshwater clays (not in situ) with *Elephas meridionalis*.[3]	
GUNZ-SCANIAN.	Not known.	

For footnotes to the above table see preceding page.

I thank Professor Hickling for his interest in the publication of this paper.

Some Grindstones from the Coal Measures of Yorkshire.

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INTRODUCTION.—A few years ago Mr. W. J. Rees had occasion to analyse samples of sandstones from the Coal Measures of Yorkshire, which had been used for the grinding of tools and rough castings. As the unused portions of the original samples were still available, it was thought that a record of these analyses, accompanied by petrological descriptions of the stones, might be of interest and of use. The subject of grindstone petrology is one which appears to have received little attention in this country. Merrill, however, in 1905,[1] gave brief descriptions of various grindstones then used in America; among these he included the "Wickersley Rock", which here receives further attention.

As very few descriptions of Coal Measure sandstones, approximating to the normal type,[2] have been published accompanied by analyses, it is with the intention of supplying a want that fuller descriptions of the sandstones have been given than may be deemed necessary were they considered merely as grindstones. This desire for a measure of completeness has led also to the addition of notes on the heavy minerals which the rocks contain.

THE GRINDSTONE HORIZONS.

No quarries depend solely on the output of grindstones for their existence or continuance. Certain beds, or, as frequently happens, certain localized sections of a bed, alone yield a sandstone which is suitable for grinding purposes. Among other things, local increase in the percentage of iron-oxide, as in "ochre balls", may render many cubic feet of a sandstone bed totally useless for the production of grindstones. Again, the size of the joint-blocks limits the size of the grindstones which can be produced from them, and this has its effect upon the output. As a consequence it is found that in every case the output of grindstones is merely an incidental feature in the working of a quarry for building stone.

At certain horizons in the Lower and Middle Coal Measures of South and West Yorkshire beds of sandstone occur which are noted for the excellence of the grindstones which they yield. The most widely known of these is the *Wickersley Rock*. This is the highest important sandstone in the Middle Coal Measures of South Yorkshire, and occurs about 2,000 feet above the Barnsley Coal. It is quarried largely for building stones and grindstones in the neighbourhood of Silverwood and Wickersley, about 3 miles east of Rotherham. It is a soft, light-brown or buff-coloured stone, thickly bedded and reaching a maximum thickness of about 100 feet.

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[1] George P. Merrill, *The Non-metallic Minerals: their Occurrence and Uses*, 1st ed., 1905, 388–97.

[2] Ganister and crowstone, which have received full attention in recent publications of H.M. Geological Survey, are here regarded as exceptional types.

At an uncertain horizon, but one which is high above the workable coals of the Middle Coal Measures, is the *Ackworth Rock.* This has been largely wrought for building stone and grindstones on Ackworth Moor Top, about 6 miles E.S.E. of Wakefield. The sandstone is light brown, somewhat friable, very thickly bedded, and attains a thickness of about 120 feet.

In the lower part of the Lower Coal Measures are found two grindstone horizons. The higher, known in the Sheffield district as the *Brincliffe Edge*, or *Greenmoor Rock*, occurs from 500 to 600 feet above the Ganister Coal. The rock, which is buff and sometimes greenish coloured, is a finely grained, thinly laminated, durable flagstone. It is usually thinly bedded, but locally, as at Brincliffe, may be massive. This sandstone horizon is almost continuous across the coalfield, and can be traced to the south into Derbyshire as the Wingfield Flags and to the north as the Elland Flags. At many places it is largely worked for flags and building stones, and also for stones which are specially selected as being suitable for tool grinding.

Close to Sheffield, about 50 to 100 feet above the Ganister Coal, is a hard, close-grained rock, the *Loxley Edge Rock.* This is typically fine-grained and flaggy, but in places coarse and gritty, as at Loxley Edge and Greystones. Where quarried at Bole Hill and Walkley, it is thick-bedded, but not particularly coarse, and is primarily a building stone, the grindstone output being small. It reaches a maximum thickness of 200 feet near Walkley, but thins to less than a quarter of this thickness within a mile or two to the south and to the north of this locality.

ANALYSES.

The following chemical analyses were made from samples of actual grindstones obtained from the localities named, and each represents the average of two analyses :—

	Silverwood.	*Ackworth.*	*Brincliffe.*	*Walkley.*
SiO_2	80·03	81·54	74·30	88·10
Al_2O_3	10·78	8·56	12·71	6·49
Fe_2O_3	2·26	2·86	3·97	0·78
TiO_2	0·47	0·37	0·71	0·43
CaO	0·42	0·35	0·54	0·13
MgO	0·56	0·38	0·86	0·25
K_2O	1·61	1·74	1·84	1·16
Na_2O	0·95	1·31	0·88	1·02
Loss on Ignition .	2·84	2·81	4·07	1·57
	99·92	99·92	99·88	99·93

These analyses indicate the following approximate mineralogical compositions for each rock :—

	Silverwood.	*Ackworth.*	*Brincliffe.*	*Walkley.*
	%	%	%	%
Quartz . . .	62	67	55	75
Felspar and Mica (fresh and in various stages of decomposition) .	35	30	41	24
Limonite . .	3	3	4	1
	100	100	100	100

MICROSECTIONS.

The following descriptions refer to slices cut from the grindstone specimens analysed :—

Wickersley Rock. Silverwood. (Text-fig. 1.)

This is an even-grained sandstone composed of angular and subangular grains, with average diameter about 0·20 mm. Some of the larger grains have a diameter of 0·25 mm., while the smaller ones are not above 0·05 mm. The grains consist chiefly of quartz, with much turbid and a little fresh felspar. The quartz contains some liquid inclusions as in granite. Some small compound quartz aggregates are present with sutured junctions. Clear patches composed of secondary silica, but similar in size and shape to the clastic grains, are also present. Fragments of microcline, showing cross-hatching with varying distinctness, and a little plagioclase

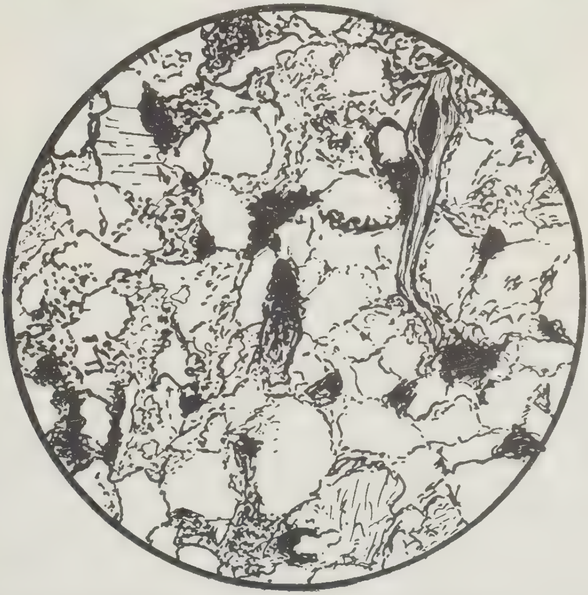

FIG. 1.—Wickersley Rock, Silverwood. Camera lucida diagram. × 70 diam.

occur. The decomposition of the felspar is often so far advanced as to render the physical constants of the original mineral indeterminable. Mica flakes are abundant and uniformly distributed. They are often contorted and lap round the grains of quartz and felspar. Muscovite is certainly present, but a great part of the mica appears to be a bleached biotite, the iron oxide turned out now being found as lenses of limonite along the cleavage planes. Other dark micas have been found in course of alteration to chlorite. Rounded detrital apatites and an occasional tourmaline and zircon have been seen in slices.

The interstitial or packing material is more in evidence than that of either the Loxley Edge Rock or the Ackworth Rock. It is fairly uniformly distributed, and consists of secondary chlorite, limonite, sericite and secondary silica from the break-down of felspar and mica. The chlorite is pale green or colourless except where it adjoins the opaque grains of iron oxide, when it assumes a yellowish-green appearance. The mica flakes contribute very largely to the relatively soft packing material in which the harder grains are embedded.

Ackworth Rock. Ackworth Moor Top. (Text-fig. 2.)

In this rock the grains are angular or subangular, and notably variable in size, their greatest diameter varies from 0·30 to 0·05 mm., the dominant diameter being about 0·20. Compound grains are rare, but many of the quartz grains exhibit strain shadows, and liquid inclusions of granitic type are common. A few of the grains also enclose minute crystals of greenish-blue pleochroic tourmaline. Of the few patches of secondary silica (whose size and shape agree with those of the clastic grains) some are clear while others enclose scattered scales of micaceous or chloritic substances. The fresh felspars are principally plagioclase, extinguishing at angles up to 20°, and microcline. The majority of the felspar grains have undergone alteration with the production of secondary silica and minute flakes of sericite. Ragged, curved flakes of clastic white mica are abundant. These appear to have been produced by the bleaching of a coloured mica, some of which still shows pleochroism from a distinct purplish tinge to almost colourless. In other instances the coloured mica has been converted into chlorite. Tourmaline and zircon have been detected as separate grains in microsections.

The grains are close-set and the thin interstitial material is uniformly distributed through the rock. In this respect a likeness to the Walkley Rock is seen. This interstitial material consists of chlorite, limonite, and secondary silica, but much of the last-mentioned mineral tends to form aggregates as separate patches rather than to form a thick film on the surfaces of the original quartz grains. Limonite occurs as irregular grains, the largest having a diameter of 0·50 mm. Some of this mineral is detrital, the rest comes from the decomposed biotite or from secondary chalybite and pyrites. It merely stains the chloritic substances in contact with it, and is not uniformly distributed, although in places it alone forms the cement.

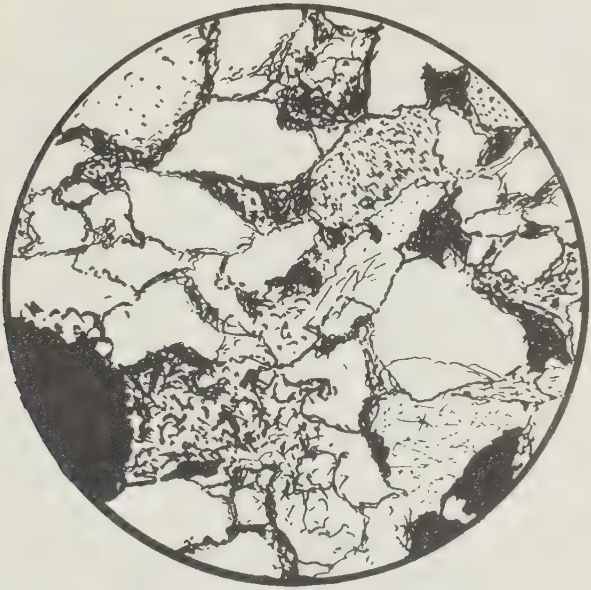

FIG. 2.—Ackworth Rock. Camera lucida diagram. × 70 diam.

Brincliffe Edge Rock. Brincliffe, Sheffield. (Text-fig. 3)

This is a uniformly fine-grained rock, the grains of which are angular and vary from 0·10 mm. to 0·02 mm. in diameter, the dominant diameter being about 0·05 mm. The quartz grains contain numerous liquid and other inclusions. Some, which are clear, are apparently secondary growths of silica from which foreign matter, such as limonite, has been expelled unilaterally and concentrated to an unusual degree. Fresh felspar is present in small amount, and is mainly plagioclase, with some orthoclase. Flakes of white mica are present.

The chief constituents of the matrix in which the hard grains are set are chloritic substances and limonite. The latter is more generally distributed through the rock than it is in any of the other stones described. Secondary silica, sericite and barytes occur in smaller amount. On the whole the various interstitial minerals are evenly distributed, but the barytes and some strange aggregates of chlorite with secondary silica occur in isolated patches.

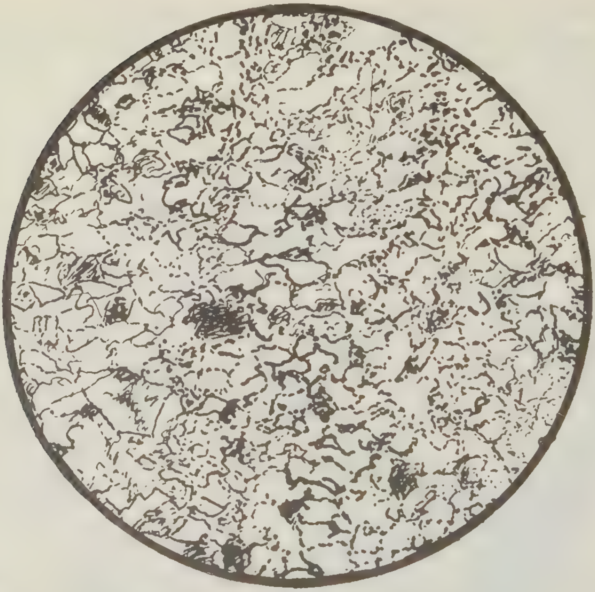

FIG. 3.—Brincliffe Edge Rock, Brincliffe. Camera lucida diagram. × 70 diam.

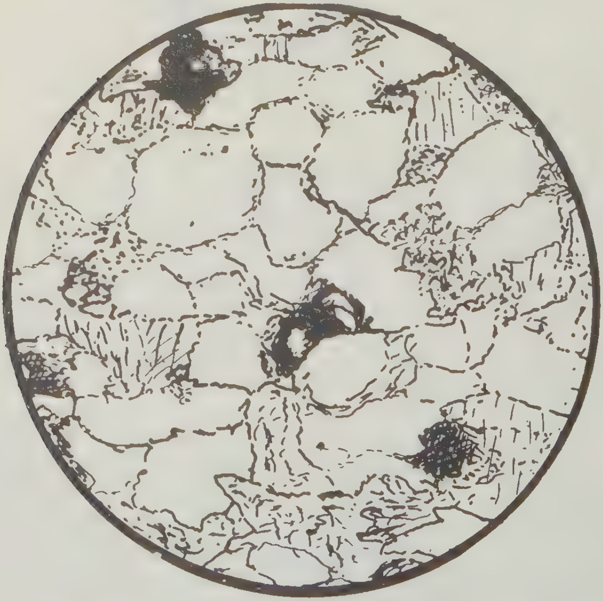

FIG. 4.—Loxley Edge Rock, Walkley. Camera lucida diagram. × 70 diam.

Loxley Edge Rock. Walkley, Sheffield. (Text-fig. 4.)

The larger grains in this rock have a diameter of 0·30 mm. and the smaller of 0·01 mm., the dominant grain size being 0·25 mm. to 0·20 mm. The grains are fairly uniform in size, and while the larger grains may be somewhat rounded the smaller are angular. Within many of the quartz grains characteristic greenish-blue prisms of pleochroic tourmaline,[1] needles of rutile and zircons have been noticed. The quartz grains frequently show strain shadows. Fresh, somewhat oval grains of microcline, oligoclase and orthoclase are also present, but they are usually of small size. Some curved flakes of white mica occur.

The relatively soft interstitial packing material is in less amount in this rock than in any of the others here described. Chlorite, sericite, and limonite are the chief constituents of this material, which is of fairly uniform character in all parts of the rock. Most of the quartz grains have sutured junctions, which suggests the addition of secondary silica, possibly derived from the internal breakdown of felspar.

ESSENTIAL FACTORS.

A review of the features which these stones exhibit enables us to summarize the factors which have contributed towards their success as grindstones. Probably the best known and most successful of these grindstones are those selected from certain beds of the Wickersley Rock. These stones show certain special features, but we may accept them as a central type from which stones from other localities depart in certain particulars.

The Cutting Grains.—The grains effective for cutting are almost wholly of quartz, for the quantity of other fresh compact mineral is never great.[2] As deposited the sediment was fine sand, superfine sand, or silt. The grains show varying degrees of angularity, the larger grains being in general subangular and the smaller sharply angular. The angularity may in a few cases be due to secondary growth, as suggested by Phillips.[3] The distribution of the grains and the matrix is so uniform that hard " knots " and soft spots do not trouble the user and under the microscope are practically absent.

The percentage of free silica is shown by the analyses to vary from 60 per cent to about 70 per cent for the best stones composed of fine sand and coarse silt. In the Brincliffe Rock the free silica content falls to 55 per cent, but the relative decrease in the grain-matrix ratio is offset by the marked reduction in grain size in this rock (see Text-fig. 5). On the other hand, in the Walkley Rock, notwithstanding its slightly coarser grain, the percentage of free silica is rather too high in comparison with that of the standard grindstone.

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[1] Phillips noted the presence of " schorl " needles in the quartz grains of a Lower Coal Measure Sandstone from Spinkwell Quarry, near Bradford. J. A. Phillips, "The Constitution and History of Grits and Sandstones": *Q.J.G.S.*, vol. xxxvii, 1881, p. 11.

[2] The quantity of fresh felspar present is comparatively small, and although the heavy crops of the sandstone (see p. 25) contain such minerals as garnet, apatite, zircon, etc., these are present in such small amount that they influence in an almost insignificant degree the cutting action of the rock.

[3] J. A. Phillips, ibid., pp. 11–12.

The "Bond".—It is noteworthy that although the rock formations from which the grindstones were selected possess a cement which is frequently in part and sometimes wholly a mixed carbonate mineral, yet in the grindstones themselves little or no carbonate has been detected. The bulk of the interstitial material is typically argillaceous, and mainly composed of flexible and elastic minerals. which are cleavable into minute soft scales and which are not brittle as the carbonate minerals are. Moreover, these minerals are such in nature, amount, and distribution that, while they separate the grains, they are themselves cemented, probably by silica, in such a manner as to give adequate strength to the stone. At the same time they are powdered away during use so as to bring fresh grains and fresh edges constantly into action when abrasion is proceeding.

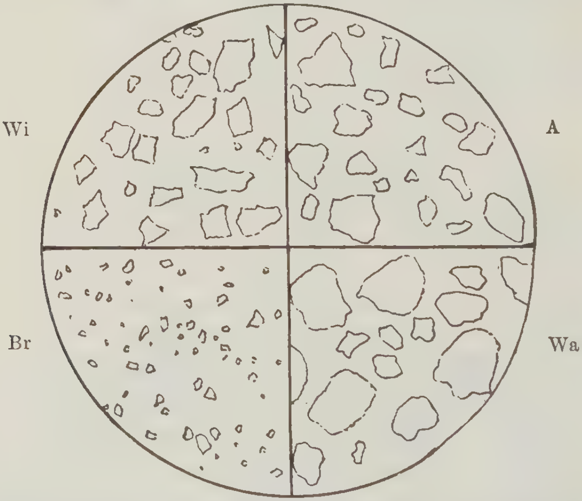

FIG. 5.—Quartz grains of characteristic size and shape separated from the Wickersley (Wi), Ackworth (A), Brincliffe (Br), and Walkley (Wa) grindstones. × 35 diam.

On Mohs' scale the hardness of the bulk of the minerals in the matrix is from about 2 to 2·5. Taking instead of Jagger's microsclerometric method for finding absolute hardness,[1] that of Rosiwal, 1896, who grinds with a standard powder, as being more applicable to the matter in hand, we find that the quartz grains of grindstones are about one hundred times as hard as the argillaceous matrix in which they are imbedded, and that a calcite cement would be from three to four times as hard as the argillaceous packing materials.

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[1] *Amer. Journ. Sc.*, vol. iv, 1897, p. 399.

There is a tendency when too much interstitial material is present for the stone to be soft and friable. The quartz grains then fall out and the stone wears away too rapidly, the article being polished becomes scored and grooved by the loose particles and is thus left with its surface coarse and uneven. On the other hand a stone with little packing and much cement, especially if that be siliceous, is too hard. It then either "glazes", "loading" or clogging its interspaces with the material which is being ground, and loses its cutting qualities, or cuts so slowly as to be no longer desirable. The softer stones such as those of Ackworth are usually employed for grinding the harder steels and the harder stones of the Walkley type are used for grinding softer metal.

The stones selected for the making of grindstones must be free from cracks, concealed joints, or flaws of any kind, because in use they are frequently rotated at speeds varying from 2,500 to 4,500 feet per minute, and are liable to fly or fracture. For the same reason a stone with a weak cement, especially a large one such as is used for grinding castings, is liable to "burst" and cause injury to workmen and machinery.

NOTES ON THE HEAVY MINERALS.[1]

The minerals which have been identified in the sandstones are as follows :—

Cubic.
garnet.
magnetite.
pyrites.

Tetragonal.
anatase.
rutile.
zircon.
xenotime.

Rhombohedral.
apatite.
carbonates.
ilmenite.
quartz.
tourmaline.

Orthorhombic.
barytes.
brookite.
staurolite.

Monoclinic.
chlorite.
epidote.
ferromagnesian micas.
monazite.
muscovite.
orthoclase.

Triclinic.
microcline.
oligoclase.

Other minerals.
limonite.
leucoxene.

The distinctive characters of some of the above minerals which have not been mentioned previously will now receive attention.

Wickersley Rock. Uppermost Middle Coal Measures.

Garnet.—One or two grains of irregular shape have a diameter f 0·15 mm., the remainder are smaller (0·1 mm. to 0·05 mm.).

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[1] These notes and the table which accompanies them refer only to the minerals separated from the grindstone samples, except where there is a statement to the contrary.

With the exception of one brown grain, the garnets are either colourless or possess a faint pink tinge.

Magnetite.—A few shiny black grains occur, some of which show good crystal shape, while the rest are rounded (0·15 mm.).

Anatase.—Represented by small dark tabular crystals (0·05 mm.), with sharp angles, forming aggregates of secondary origin.

Rutile.—This mineral is represented by the foxy-red, often almost brown, variety and the orange-yellow variety in about equal amount. Both types display a marked adamantine lustre. Angular fragments (0·1 mm.) are most frequent, but more or less perfect, stout and thin prismatic forms are common (0·15-0·3 mm. long).

Zircon.—Mainly short, stumpy, sometimes rounded, colourless crystals (0·1 mm.), with a fair number of larger crystals (0·15–0·2 mm.) showing better developed prisms and occasionally also the basal plane. Long, thin acicular forms are rare. Inclusions are frequent, but the larger crystals are often free from inclusions and clear or zoned.

Xenotime.—Two or three yellow crystals (0·1 mm.) of bipyramidal shape, with prisms more or less developed, are referred to this mineral.

Apatite.—This is the most abundant mineral, exceeding even zircon in amount. A large number of prismatic crystals (0·15 mm.) are present, but the grains for the most part are either irregular or rounded The prismatic crystals with rounded ends. are usually colourless and clear, a few contain inclusions of zircon and other minerals. The remaining grains are frequently dirty and have very low birefringence.

Ilmenite.—Rarely fresh, but grains coated with leucoxene (0·1–0·2 mm.) are much more abundant than magnetite grains.

Tourmaline.—Brown (occasionally blue) prismatic forms (0·12 mm.) with irregular terminations are most frequent. Smaller crystals with well-defined rhombohedra, irregular fragments and well-rounded grains are also found. Inclusions are somewhat common.

Barytes.—A few angular flakes up to 0·25 mm. in diameter are derived from the cement.

Brookite.—Tabular fragments (0·15 mm.), usually showing conchoidal fracture and varying from bright yellow to straw colour, according to thickness, are present in good amount.

Staurolite.—One or two small angular pleochroic grains (0·12 mm.) have been seen of a deeper yellowish-brown colour than that of the grains of this mineral found in the neighbouring Permian rocks.

Chlorite.—Pale-green scales (0·1–0·05 mm.) giving extremely low birefringence colours are occasionally seen and are probably derived from mica.

Epidote.—Only one characteristic greenish-yellow, slightly rounded prismatic grain (0·12) has been seen.

Ferromagnesian Micas.—One or two small pleochroic flakes may be biotite. A green mica is also present as rounded flakes (0·15 mm.).

Monazite.—Two rounded grains (0·15 mm.) with high refractive indices and a greenish-yellow tinge are referred to this mineral.

Muscovite.—Flakes extremely common up to 0·5 mm. in diameter. Strain shadow effects are exhibited by some. Minute flakes probably of a secondary sericitic substance are of frequent occurrence.

Limonite.—Common throughout as brown or brownish-red opaque grains with irregular outline and up to 0·5 mm. in diameter.

Ackworth Rock. Uppermost Middle Coal Measures.

Garnet.—Far more abundant than in the Wickersley samples. The grains are for the most part colourless, but angular brown fragments and rounded and angular pink grains (0·2 mm.) also occur. Angular grains of irregular outline, a few showing forms with re-entrant angles similar to those figured by Professor Boswell from Inferior Oolite and Upper Liassic sands,[1] predominate. Some long, narrow-pointed fragments attain a length of 0·5 mm. A few grains are rounded. Inclusions and the characteristic cracks are well-marked features.

Magnetite.—Fairly common as rounded grains. Occasionally well-defined octahedra (0·15) of this mineral are seen.

Pyrites.—One good crystal (combination of pyritohedron and the cube, 0·15 mm.) has been seen.

Anatase.—Small colourless crystals (0·04 mm.) are found in closely packed aggregates and arranged in parallel rows in a matrix of what appears to be leucoxene. These are evidently in the position of their growth within the sandstone.

Rutile.—Occurs abundantly either as short crystals (0·12 mm.) or as longer prismatic crystals and fragments (0·25 mm. long). The mineral is opaque to transparent, and the colour varies from foxy-red to almost lemon-yellow.

Zircon.—As in the Wickersley Rock, short, stumpy and rounded crystals predominate (0·1 mm.), although good crystals up to 0·25 mm. in length are common. Only very few show a development of the basal plane. One or two large (0·35 mm.) crystals of distinct "anvil" shape have been noted.

Xenotime.—Two yellow grains may be referred to this mineral.

Apatite.—This mineral occurs in far less quantity than in the Wickersley Rock. It is mainly represented by prismatic crystals with rounded ends and by angular fragments (0·10–0·25 mm.), but a few oval and spherical grains (0·20 mm.) are present. Inclusions of other minerals are frequently found within the prismatic crystals.

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[1] P. G. H. Boswell, "The Petrography of the Sands of the Upper Lias and Lower Inferior Oolite in the West of England": Geol. Mag., Vol. LXI, June, 1924, p. 253, Fig. 2.

Ilmenite.—Angular grains of this mineral coated with leucoxene are abundant (0·1–0·25 mm.). One good crystal has been seen.

Tourmaline.—Chiefly prismatic forms with irregular terminations (0·15–0·2 mm.). A few rounded prisms and angular grains are present. Brown is the predominating colour, but two or three blue prisms have been seen. Inclusions are fairly common.

Barytes.—Only two or three cleavage fragments have been noticed.

Brookite.—Present in small amount as tabular bright-yellow fragments, a few of which are striated (0·15 mm.).

Staurolite.—The dark-coloured variety present in the Wickersley Rock is in this rock more abundantly represented. Small fragments (0·1 mm.) show the characteristic jagged outline, but the majority of the grains are larger (0·15 mm.) and angular.

Chlorite.—Some flakes stained by iron oxide are present.

Epidote.—Several greenish-yellow, more or less rounded, prismatic crystals (0·15 mm.) occur.

Ferromagnesian Micas.—One or two flakes of biotite have been seen, but the most conspicuous mica is one occurring as moderately dark green, somewhat rounded flakes (0·12–0·2 mm.).

Monazite.—A few almost spherical grains (0·15) are present, having the characteristic refractive index and colour of this mineral.

Muscovite.—Rectangular flakes up to 0·5 mm. in diameter are common, and occasionally show strain shadows.

Limonite.—This occurs as grains and as a brown or yellow coating to other minerals.

Brincliffe Edge Rock. Lower Coal Measures.

Garnet.—This mineral is rare, only one or two rounded, colourless grains (0·1 mm.) have been seen.

Magnetite.—A few fresh rounded crystals (0·06 mm.) have been detected, the majority are more or less associated with limonite.

Anatase.—Is represented by one or two isolated, colourless grains (0·04 mm.).

Rutile.—An occasional long orange-coloured prismatic crystal (0·12 mm.) and several smaller more or less rounded grains (0·05–0·1 mm.) of this mineral are present.

Zircon.—Rounded, stunted crystals rarely exceeding 0·05 mm. in length are abundant. Longer thin prisms (0·1 mm.) are comparatively few in number. Occasionally a sharp bipyramid, with little or no development of prisms, is seen. Zoning is common to the larger and better shaped crystals. Inclusions are of general occurrence.

Apatite.—This mineral is present as small prismatic crystals, from 0·05–0·1 mm. in length and few in number.

Ilmenite.—Is common as irregular fragments, coated with leucoxene (0·1–0·15 mm.).

Tourmaline.—Mainly represented by brown, intensely pleochroic prismatic crystals capped by rhombohedra (0·075 mm.).

Barytes.—This mineral occurs as cleavage fragments derived from the cement (0·05–0·1 mm.).

Brookite.—Is the characteristic titanium mineral, and occurs as angular, sometimes tabular and prismatic fragments, which are yellow and often striated (0·05–0·1 mm.).

Chlorite.—Occurs as rounded flakes (0·15 mm.), pale green and with extremely low birefringence.

Monazite.—Two grains (0·05 mm.) referable to this mineral have been noticed.

Muscovite.—Minute flakes of white mica (0·02–0·1 mm.) are exceedingly common.

Limonite.—Is of general occurrence either as grains of irregular shape (0·15–0·2 mm.), or as a coating material on other minerals.

Separations were also made from the Greenmoor Rock of Greenmoor. In the samples used carbonate minerals were abundant, but otherwise the heavy minerals agreed in nature and relative abundance with those obtained from the Brincliffe Rock.

Loxley Edge Rock. Lower Coal Measures.

Garnet.—Only a few colourless, slightly rounded fragments (0·2 mm.) have been seen.

Magnetite.—Is represented by a few rounded octahedra (0·2 mm.), together with some opaque shiny grains of less regular shape.

Anatase.—Occurs in aggregates, which, except for the fact that the individual crystals are of a faint yellow colour, are similar to those found in the Ackworth Rock.

Rutile.—Is very abundantly represented by foxy-red, wine-coloured and orange grains having conspicuous adamantine lustre, and, when clear, pleochroism. In the main the grains are angular (0·15–0·3 mm.), showing crystal facets, but more or less rounded prisms (0·15–0·35 mm. long), together with two or three almost spherical grains (0·12 mm.), are common. Geniculate twins are also found.

Zircon.—The smaller crystals (0·12 mm.) are in a few cases unworn, but are usually more or less rounded. Some of the smaller grains are the broken-off ends of larger crystals. Zoned crystals (0·2–0·3 mm.), with well-developed prisms and numerous inclusions of minute zircons of similar shape, usually arranged parallel to the pyramid edge, are not infrequent.

Ilmenite.—This is represented by a few fresh angular grains (0·25 mm.) showing crystal facets and by many grains coated to a greater or less extent by leucoxene. Occasionally ilmenite, leucoxene, and brookite, or rutile, are so closely associated as to constitute one grain, thus showing the interrelationship of these minerals.

Tourmaline.—Abundantly represented by prismatic crystals (0·2 mm.), angular fragments (0·15 mm.) and spherical or oval grains (0·25 mm.). Most of the grains are brown, and many contain inclusions. Blue grains are frequently encountered, together with one or two grey, discoloured fragments.

Brookite.—Commonly occurs as fragments (0·15–0·25 mm.) of a deep yellow to straw colour, sometimes with striations.

Staurolite.—Only three irregularly shaped grains have been seen, one of these (0·2 mm.) possessed the typical jagged outline. The optical properties are similar to those exhibited by the grains of this mineral separated from the Ackworth and Wickersley Rocks.

Ferromagnesian Micas.—Biotite is sparingly present as small, somewhat discoloured flakes (0·15 mm.). One or two flakes of a pale green mica were also noted.

Monazite.—Two rounded grains (0·2 mm.) of this mineral have been seen.

Muscovite.—Common as rounded and rectangular flakes up to 0·6 mm. in diameter.

Limonite.—Occurs as brownish-yellow irregular fragments up to 0·4 mm. in diameter.

The heavy mineral assemblage from the coarser Loxley Edge Rock at Greystones much resembled the heavy crop from the Walkley samples in the absence of apatite, abundance of rutile, fair representation of tourmaline, and scarcity of garnet. Epidote was represented by two grains (0·2 mm.) in the Greystones samples.

TABLE OF HEAVY MINERAL OCCURRENCES.

	Anatase.	Apatite.	Barytes.	Biotite.	Brookite.	Chlorite.	Epidote.	Garnet.	Ilmenite.	Limonite.	Magnetite.	Mica (Green).	Monazite.	Muscovite.	Pyrites.	Rutile.	Staurolite.	Tourmaline.	Xenotime.
MIDDLE COAL MEASURES.																			
Silverwood .	2	10	5	5	5	6	1	5	7	10	4	4	1	10	–	8	4	6	1
Ackworth .	2	6	4	5	3	6	5	10	6	10	5	5	2	10	1	7	6	7	1
LOWER COAL MEASURES.																			
Brincliffe .	1	4	8	5	8	6	–	2	9	10	6	–	1	10	–	7	–	5	–
Walkley .	3	–	–	5	7	4	1	4	7	10	4	2	1	10	–	10	2	8	–

1 = exceedingly rare.
2 = rare.
3 = very scarce.
4 = scarce.
5 = frequent.
6 = very frequent.
7 = abundant.
8 = very abundant.
9 = dominant.
10 = ultra-dominant.

The heaviest yield of heavy minerals was given by the Ackworth samples and the lowest by those from Brincliffe, while from the Walkley and Silverwood Rocks the percentage yields were about equal.

Conclusions.—Much more detailed and extensive work needs to be done on the coarse and fine sediments of the North-East Midland Coalfield before anything like accurate generalizations can be put forward concerning their source of supply, but on reviewing the results stated above certain outstanding features claim our attention.

For instance, certain resemblances and at the same time certain differences are indicated between the Coal Measure Sandstones and the Millstone Grit.[1] Resemblance is found in the continued abundance of rutile and zircon, and, in some cases, of ilmenite, tourmaline and garnet, and also in the presence of monazite; differences in the presence of staurolite,[2] apatite and epidote, and in the almost total absence of garnet in some cases. There is here, therefore, an indication that the source of supply had, in a measure, changed even in Lower Coal Measure time from what it had been during the Millstone Grit period.

Again, comparison of the Lower Coal Measure minerals with those of the Uppermost Middle Coal Measures appears to show that whereas a certain amount of resemblance in nature and amount is still evinced by certain mineral species, for example rutile, zircon and tourmaline, there is a tendency for the heavy mineral assemblage of the Wickersley and Ackworth rocks as a whole to approximate in character to that which has been described for the Permian deposits to the east.[3] This is shown by the relative increase in such minerals as staurolite, apatite and epidote, and in the abundance of large and often coloured garnets.

In conclusion we wish to express our thanks to Professor W. G. Fearnsides and Mr. W. H. Wilcockson for helpful advice and many useful suggestions.

The Pluvial Period of Central and Southern Italy.

By the late F. W. Harmer, F.G.S.

(PLATE II.)

[Introductory Note.—The typoscript of this paper was found by me among my father's MSS., after his death on 11th April, 1923. There was evidence to show that it was written rather earlier than 1908, and it is obviously the first part of a paper which had been put on one side during the preparation of "The Pliocene Mollusca of Great Britain". The typoscript ended with the heading "Floods of Miocene and Pliocene Periods", but I have no reason to believe that this section was ever prepared. The three figures here reproduced were with the typoscript, but others which it had been intended to use in illustration of the paper have not been found.

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[1] Dr. A. Gilligan, "The Petrography of the Millstone Grit of Yorkshire": *Q.J.G.S.*, vol. lxxv, 1920, p. 263.

[2] Professor Kendall has recorded Professor A. Gilligan's discovery of this mineral in the Yorkshire Coal Measures. See *Geology of Yorkshire*, 1924, p. 163.

[3] See A. Gilligan, "The Lower Permian at Ashfield Brick and Tile Works, onisborough": *Proc. Yorks. Geol. Soc.*, xix, pp. 289–97, 1918. H. P. Lewis, "Detrital Barytes in Permian Basal Sand at Nitticarhill": Geol. Mag., ol. LX, 1923, pp. 307–13, and H. C. Versey, "The Beds underlying the agnesian Limestone": Report of *Proc. Yorks. Geol. Soc.*, 5th April, 1924. bs. Geol. Mag., August, 1924, Vol. LXI, pp. 380–1.

SIDNEY F. HARMER.]

BRITISH MUSEUM NATURAL HISTORY.
December, 1925.

THE view that some part of the Pleistocene epoch was characterized by excessive rainfall is by no means new. The term " pluvial " was first used by the late Alfred Tyler, in some well-known papers, one, on the Amiens gravels, read before the Geological Society of London in 1868, where he pointed out that the quaternary valley deposits found in Northern France and elsewhere could only have been accumulated under meteorological conditions very different to those now existing.[1] During the following year, in a second paper on " the Formation of Deltas ", published at first in abstract,[2] and afterwards in full,[3] he expressed the opinion, *inter alia*, dealing with the conditions obtaining at the same period in N. America, that the width, depth, and coarseness of the fluviatile deposits of the Mississippi represent a rainfall sevenfold greater, and a current nearly twice as rapid as that of the present river.[4]

The following facts, out of many similar ones I have observed in the south of Europe during recent years, seem to support Tyler's hypothesis. Some of the most striking of these are to be found in Tuscany, in the valley of the River Arno, at San Giovanni, 30 miles above Florence.

The well-known lacustrine Pliocene strata of the Val d'Arno, which are of considerable thickness, reaching at this spot to a height of about 300 metres above sea-level, occur there in a wide and deep valley, excavated out of the Eocene strata of the Apennines. The most casual observer, travelling from Arezzo, near the head-waters of the Arno, to Florence, can hardly fail to notice the phenomenal erosion to which these deposits have been subjected. For a distance of more than 30 miles the railway traverses a country intersected by innumerable and incessantly recurring ravines and cañons of the most remarkable character. Fig. 1, copied from the Government Map on the $\frac{1}{50000}$ scale, which represents a small area, only about 10 miles in length, shows the extraordinary frequency of these gorges near the small villages of Persignano and Piantravigne, situated on the hill-side, a short distance from San Giovanni, which I visited at the suggestion of Professor Ristori of Florence, who informed me that the features there presented are characteristic of the entire region alluded to.

Professor Ristori very kindly sent me some interesting photographs of the Persignano gorges, and I have since received from

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[1] *Q.J.G.S.*, vol. xxiv, p. 105, 1868.
[2] *Q.J.G.S.*, vol. xxv, p. 7, 1869.
[3] GEOL. MAG., 1872, pp. 392–9 and 485–500.
[4] Op. cit., p. 491.

Signor Ing. A. Ciampi, the Chief Engineer of the Lignite mines at Castelnuovo, some of those of Piantravigne. One of Signor Ciampi's photographs is here reproduced (Pl. II), and my best thanks are

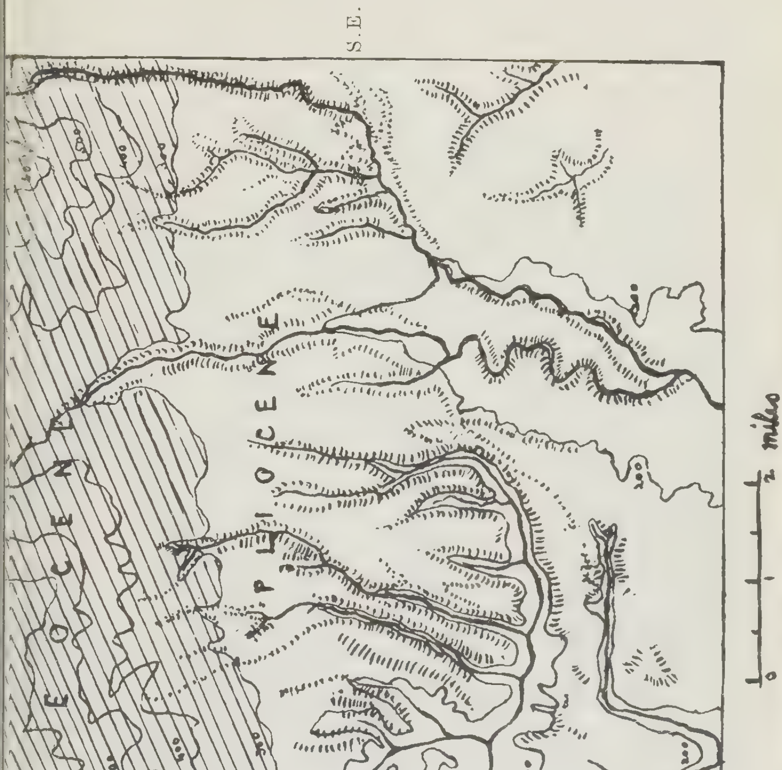

FIG. 1.—Map showing Post-Pliocene denudation of the Val d'Arno deposits near San Giovanni. The contour-lines are given in metres.

due to both gentlemen for the great trouble they have taken in the matter.

The ravines, which, when seen on the spot, remind one of the famous Colorado Cañon, though on a much smaller scale, are cut almost vertically out of the alternating beds of gravel and sand of the Pliocene deposits; to a depth in some cases, as at Piantravigne, of 40 or 50 metres. They are, however, very short, having a gradient which rises rapidly towards the mountains, against the flanks of which the Val d'Arno beds rest, and they generally end more or less abruptly, sometimes in a kind of cirque. As may be seen in Pl. II, many of these cañons, which are often of considerable width, are either cultivated to the very bottom, or are covered by vegetation. At the time of my visit they were dry, or nearly so; insignificant rills (out of all proportion to the size and width of the gorges) running in some of them in narrow channels of the depth of 2 or 3 feet or less. Although the incoherent character of the strata would facilitate the process of their erosion, Professor Ristori and some other Italian geologists with whom I had the opportunity of discussing the question believe that the peculiar features of this district could only have originated under the influence of a rainfall much greater than that of the present day.

Similar evidence of a pluvial period exists in the Roman Campagna, as for example in the neighbourhood of Palestrina, the ancient *Praeneste*. In this case, however, it is possible more exactly to define the period of its occurrence.

The district represented in Fig. 2, copied from the *Carta Geologica d'Italia* on the scale of $\frac{1}{100000}$ for which I have to thank Dr. Baldacci of the Italian Geological Survey Office at Rome, is covered by tuff, geologically recent ("tufi basaltici e leucitici incoerenti" of the Italian map) intercalated with hard beds of lava ("tufi basaltici e leucitici litoidi"), and forms an elevated plain lying between the still higher volcanic region of the Alban Hills to the S.E. and the Eocene range of the Monte Ernici on the N.W. The gorges by which this plain is longitudinally furrowed connect themselves with the valley of the Teverone, an important affluent of the Tiber. They are more elongated than the cañons of the Val d'Arno, in accordance with the different shape of the region whose torrential drainage they once carried, but they resemble them in their frequency, and in the steepness of their containing walls. Some of them seem to be at present dry, or nearly so, especially in the upper part of their course, but others contain, lower down, a sharply cut and narrow channel of no great depth or width—a gorge within a gorge—carrying a small stream or torrent.

The proportions these small watercourses bear to the main valleys may represent, as in the cases before cited, the difference between the former and the existing rainfall of the district, and the greater erosion of the Pleistocene, as compared with that of the recent epoch.

The small towns of Zagarolo, and Gallicano, stand on almost knife-edge ridges, separating some of these precipitous and parallel gorges, which are a few yards only distant from each other (Fig. 2). It is difficult to conceive the conditions under which torrents from such a limited watershed could have simultaneously poured down

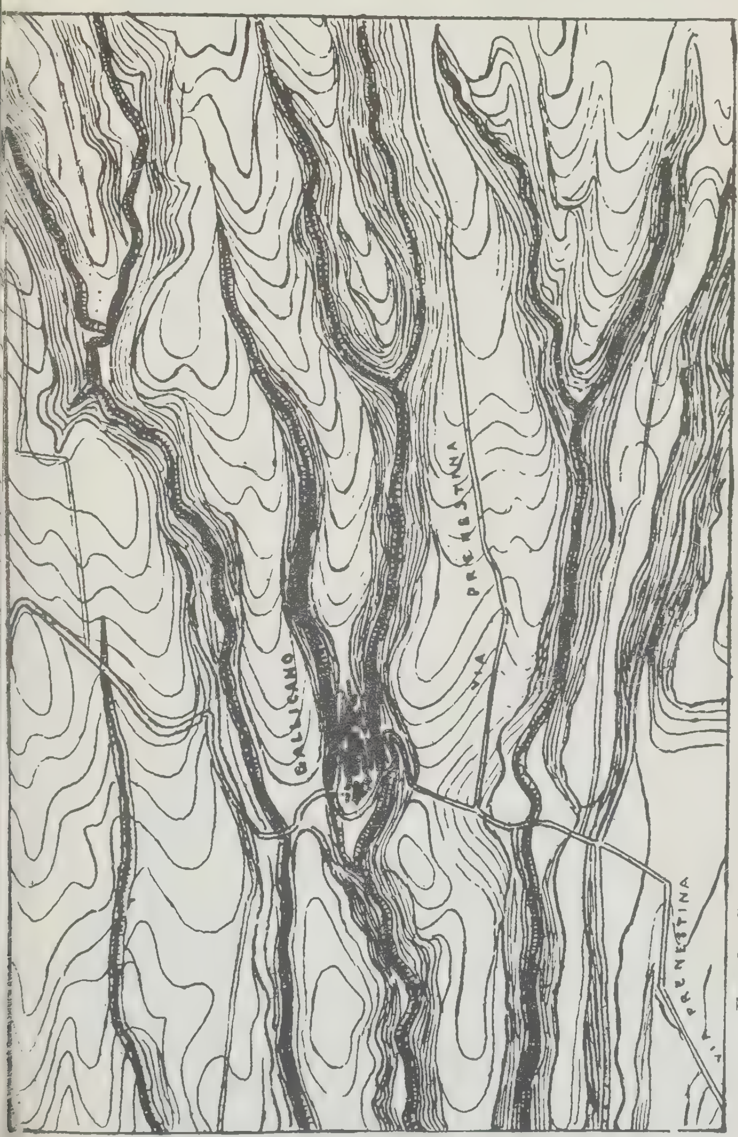

Fig. 2.—Gorges near Gallicano, E. of Rome. Copied from the Carta Geologica d'Italia.

these numerous valleys in sufficient strength to have eaten their way through the hard basaltic rock, and to have removed all the resulting débris.

It is important to notice that no material alteration in the physiography of the district seems to have taken place during the last 2,000 years. The course and position of the ancient Roman roads, as for example the *Via Labicana* and the *Via Prenestina*, show that, at the time of their construction, the condition of these gorges must have been practically the same as at present. The *Via Prenestina* crosses one of them near Gallicano, by what I was informed is a Roman bridge (Fig. 2). Thence it turns sharply to the right and follows the crest of one of the ridges towards Palestrina. At another place, I noticed, at the bottom of one of these gorges, the remains of a tessellated pavement, belonging to the road by which, from ancient times to the present day, the valley has been traversed. The *Via Labicana* also runs along and within one of these gorges towards Valmontone. The Tiber flows, moreover, through the city of Rome much as it did in the time of the Cæsars. In fact, as Professor Meli informs me, its bed has been raised rather than lowered during the interval. On the other hand, the volcanic deposits of the immediate neighbourhood, out of which these cañons have been excavated, can be shown to be newer than the later Pliocene period.[1]

In no other part of Europe do such deposits occur in equal variety or extent. They resemble those of the North Sea basin in including a series of beds of different ages, some of them containing a much larger proportion of extinct species than others. The molluscan fauna of the older horizons, that of the *argiles bleues* of the Ligurian coast, for example, seems to me, however, to differ more widely from that of the present Mediterranean than the fauna of the Coralline Crag does from that of the North Sea, and I am disposed to doubt whether any of the East Anglian Crag beds are as old as the *Plaisancian* deposits of Italy.

In Central, and even more in Southern, Italy and in Sicily, however, there are fossiliferous strata, of a much more recent character, generally referred to the *Sicilian* zone of Döderlein, representing a period when certain species of recent molluscs, boreal, and even arctic, which do not now live in the Mediterranean, were appearing in that sea for the first time. Among these may be mentioned :

Buccinum humphreysianum.	*Yoldia frigida.*
,, *groenlandicum.*	*Astarte sulcata.*
,, *undatum.*	*Cyprina islandica.*[2]

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[1] Professor C. de Stefani has well said that Italy is *la terre classique du Pliocène.*

[2] This is regarded by Meli (*Boll. Soc. Geol. Ital.*, vol. xiii, p. 163, 1895) as a distinct species (*C. aequalis* Bronn) which may, however, be a geographical variety of the northern form. It appeared at a comparatively late period in the Mediterranean, in which it is now unknown.

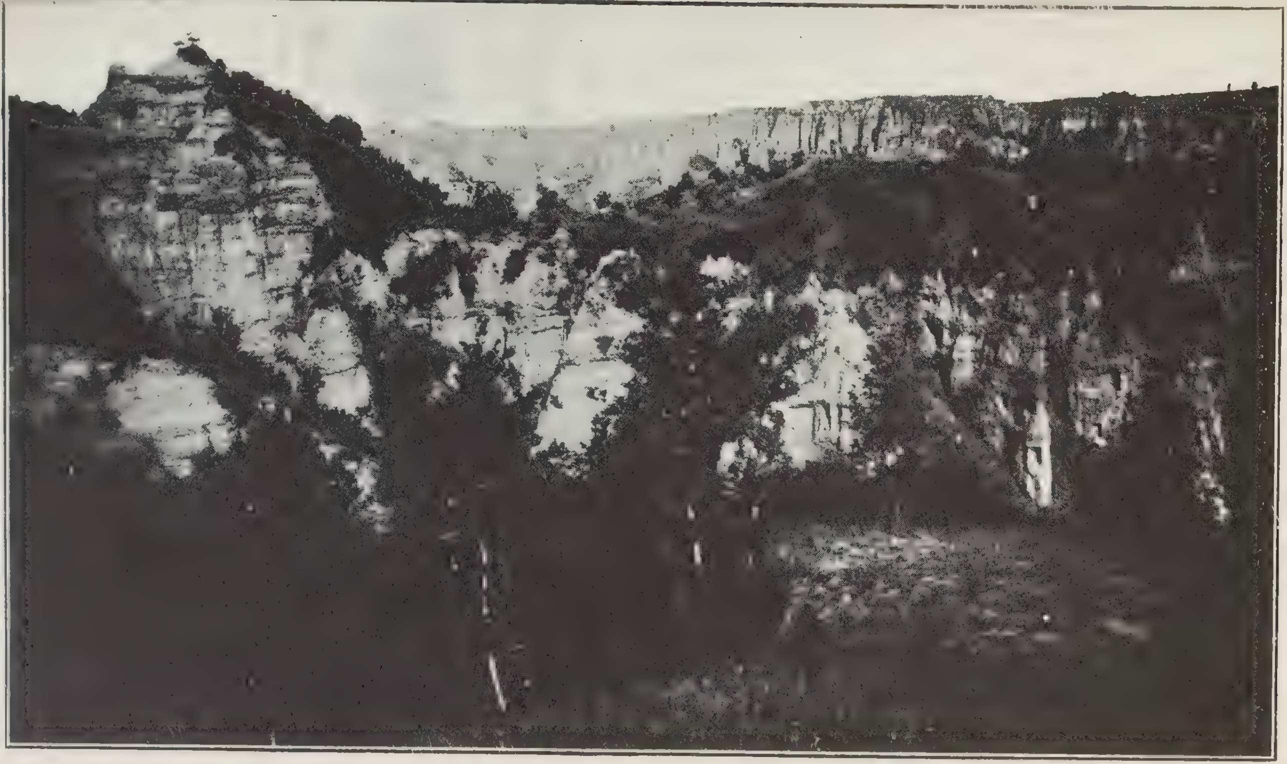

Photo Signore Ing. Ciampi.

GORGE AT PIANTRAVIGNE, NEAR SAN GIOVANNI, IN THE VAL D'ARNO.

[*To face p. 32.*

Trichotropis borealis.
Natica montacuti.
Trochus helicinus.
Pecten septemradiatus.
,, *tigrinus.*
Modiola modiolus.
Artemis lincta.
Mactra solida.
Saxicava arctica.
Mya truncata.
and others.

The northern shells are more common at some localities than at others, as, for example, at the well-known deposits of Monte Pellegrino and Ficarazzi, near Palermo, which also contain a very small proportion (not more than 1–2 per cent.) of extinct species.

Possibly the Sicilian deposits represent a considerable period, the climate of the Mediterranean region being colder than it is now, and the deposition of the different beds referred to it may have been contemporaneous with the arrival, the greatest abundance, and the dying out of the boreal Mollusca. There are some beds, however, on the flanks of Mount Etna, 1,000 feet above sea-level, which I visited under the guidance of Dr. Scalia[1] of Catania, of a still more recent character, containing none but species still inhabiting the adjacent sea, apparently belonging to a time when the northern shells had disappeared.

Considerable difference of opinion exists among Italian geologists as to the use of the terms Pliocene, Post-Pliocene, and Quaternary. The denudation of the Val d'Arno deposits, however, was at least post-Astian: moreover, the typical deposits of Asti itself have been subjected to a similar erosion, which may have coincided with that of the tufa and basalt of the Roman Campagna; the latter strata are regarded as Post-Pliocene by Italian geologists. At Monte Mario, near Rome, they overlie the well-known fossiliferous deposits of that locality, the upper part only of which contains *Cyprina* and other boreal species. The pluvial conditions under which the excavation of the gorges of Zagarolo and Gallicano took place seem therefore to have been subsequent to the first introduction of the northern shells into the Mediterranean.

In many parts of Sicily, the Pliocene and what are regarded as Post-Pliocene deposits have been much eroded, the country being furrowed by constantly recurring valleys descending to the sea, which have been excavated out of the former, the denudation extending also to the older Tertiary strata underlying them. In the east of Sicily, from Messina to Syracuse, and at Reggio, on the Calabrian side of the Straits, valleys of considerable size have been cut through strata, the upper part of which are shown in the *Carta Geologica di Sicilia* as "quaternario". A photograph kindly given me by Professor Bocca of Catania shows one of these valleys, that of the river Cossabile, near Noto, to the south of Syracuse. Many of them are, however, on a considerably larger scale. The upper

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[1] Dr. Scalia has kindly placed copies of his memoirs on these beds in the library of the Geological Society.

4 metres of the section containing *Pecten jacobaeus* and other fossils are, according to Professor Bocca, Post-Pliocene. The pluvial conditions attending the valley-denudation of this part of Sicily were, he considers, "très terrible."

I was much interested, however, in noticing that near Palermo an entirely different state of things obtains. The fossiliferous beds already referred to occupy a nearly level plain, 20 kilometres in length and about 5 in breadth, the famous "Concha d'Oro". This plain is surrounded by an amphitheatre of mountains (against which the shelly strata rest) from which it slopes seaward with a gentle gradient. A few small streams descend from the higher ground, but otherwise the Concha d'Oro shows no signs of the ravinement which has affected the later Tertiary deposits of other parts of Sicily, and it seems to represent an almost undisturbed condition of the sea-bottom of the Bay of Palermo at a comparatively recent period. Professor de Stefani regards these beds, which contain, together with some northern species, a molluscan fauna almost exclusively recent, as being decidedly newer than those of Monte Mario and Valle Biaia near Pisa, in which occur, with the northern shells, others more nearly related to the older Pliocene deposits, and a larger percentage of extinct forms. The Palermo beds he considers of glacial age, and those of Monte Mario to be intermediate between the Pliocene and Post-Pliocene.[1]

The Monte Mario beds, older, as just stated, than the period of valley-erosion to which they themselves have been subject, and overlain by the Post-Pliocene lava out of which the gorges of Zagarolo and Gallicano have been cut, represent, therefore, the period at which the northern Mollusca were beginning to invade the Mediterranean (these species only occurring in the upper part of the section), and they may be roughly equivalent to the upper part of the English Crag.

Unless some other explanation can be suggested for the absence of valley erosion in the Concha d'Oro, the Palermo beds (those of Ficarazzi and Monte Pellegrino), on the other hand, with only 1–2 per cent. of extinct species, may belong to a stage in the Pleistocene epoch later than that erosion, when the molluscan fauna generally was approximating to that of the Mediterranean at present, and yet before the northern forms had disappeared.

It seems, therefore, that a pluvial period, representing a distinct stage in the geological history, during which a phenomenal valley-erosion took place, formerly existed in Central and Southern Italy; that this was later than the elevation of the deposits which represent the first invasion of the Mediterranean by the northern shells, and older than their final disappearance, and that it was probably not only coincident with, but may have been caused by, the existence of the great ice-sheet of Northern Europe.

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[1] Professor Meli (*Boll. Soc. Geol. Ital.*, vol. xiii, 1895, p. 163) points out that most of the northern species found near Palermo, of which he gives a list of about a dozen, are absent from Monte Mario; and agrees that the latter contains a larger proportion of shells which are extinct, or found only in more southern seas.

The existence of such a state of things in Italy implies widespread and similar conditions in other parts of Europe, as well as intense meteorological disturbance in the North Atlantic, and a greater strength in the planetary circulation of the atmosphere. These must have been due to some adequate cause. At present no such reasonable explanation seems to offer itself as that of the extension so far to the south of a glacial climate increasing the temperature-gradient and the strength of the atmospheric circulation. The phenomena described could not have been merely local, but must have been due to causes operating on a grand scale and over an extended area.

It does not follow that the erosion of the Post-Pliocene epoch was everywhere contemporaneous. The advance and retreat of the ice and such tectonic changes as those already referred to must have shifted from age to age the prevalent storm-tracks and the region of greatest precipitation. If, however, the pluvial period was mainly due to a steeper temperature-gradient, the maximum rainfall may have coincided generally with the greatest extension of the ice.[1]

Of the existence of pluvial conditions in other parts of Europe during the Pleistocene epoch there seems no lack of evidence. We find it for example in the great development of Quaternary deposits in the plains of Northern Italy, and of Hungary; in the valleys of the Douro and Tagus, and their affluents, and on the northern slopes of the Pyrenees. As to the latter, a figure in the *Carte Géologique de la France*, on the scale of $\frac{1}{1000000}$, needs but little comment. The region represented by it, lying in close proximity to the Atlantic, and in the track of the storms which in Pliocene times invaded Italy and the regions further to the east, is one in which we might naturally expect to find evidence of excessive rainfall. The strength and volume of the floods which, at the period in question, carried their detritus over a comparatively level country, more than 100 miles from the place of their origin, must have been vastly different from anything of the kind which now obtains in that region.

THE PLUVIAL PERIOD IN NORTHERN FRANCE.

In the northern part of France the evidence for the former existence of greater rainfall lies, as was pointed out in the classical work of Belgrand[2] many years ago, in the phenomenal amount of valley erosion which has there taken place. This may deserve more than a passing notice, as if there is any value in the view that the rainfall was greatest when the temperature gradient was steepest, that is to say, during the maximum extension of the ice, it may throw some light on the age of the valley deposits of the Seine and the Somme, in which are found the weapons and implements of prehistoric Man.

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[1] If the reasoning here adopted be correct, evidence of similar conditions of increased rainfall and erosion during the Pleistocene Period ought to exist in North America.

[2] *La Seine*, vol. i, "Le bassin Parisien aux Âges anté-historiques," Paris, 1869.

M. Belgrand has shown that at a period, in his opinion early Quaternary, floods of great violence, descending from the more elevated region to the S.E. in which the Seine and its affluents take their rise, ravaged the plains of north-eastern France, causing much denudation ; the direction of the current being shown by the general direction of the principal valleys. Tertiary outliers of the district have a uniformly S.E.–N.W. alignment which could hardly have been produced except by currents of considerable velocity. M. Belgrand connects this "diluvial" erosion with the last elevation of the Alps. At this period, he considered, the general direction of the Seine valley was sketched out. The valleys running at right angles or nearly so to that of the latter may have been due to the cause indicated by Lord Avebury in *Quart. Journ. Geol. Soc.*, lxi, 1905, pp. 345–7. At a later stage the waters of the Seine were confined to the valley of that river which, however, ran at an elevation of about 60 m. above sea-level, its width and volume being greater than at the present day, a stage at which the gravels of the higher terraces originated. M. Belgrand insists on what I think is perfectly evident that this could only have occurred at a time when the rainfall was excessive. Eventually the Seine cut its way to a base level and flowing with a comparatively gentle current produced the sinuous and restricted channel of the lower terraces. We have then evidence apparently of a rainfall on the whole gradually diminishing from the torrential floods of the first-named stage, then the wide and deep stream by which the higher terraces were deposited, afterwards that of the lower terraces, and finally the comparatively insignificant volume of the present river. This followed a period when the valley bottoms were filled with peat, a period of smaller rainfall and of limpid streams.[1]

The remains of Man which add so much to the interest of the valley desposits of this region are found in the higher and lower terraces, and not in the "diluvial" deposits of the earlier stages, and they are constantly associated with those of extinct animals—Elephant, Rhinoceros, Hippopotamus, and others. If the greater rainfall of the Pleistocene Period in the south was due to an increased strength in the planetary circulation arising from a steeper thermal gradient over the region lying to the south of the European ice-sheet, it seems probable that the greatest rainfall may have occurred during the maximum extension of the ice and that it tended gradually to diminish, contemporaneously with the recession of the latter. In that case the diluvial inundation described by M. Belgrand may represent the climax of the glaciation of Northern Europe, and the gravels of the Seine valley successive stages in the period succeeding it. It seems hardly probable that the Hippopotamus could have flourished in the rivers of northern France when the winter climate of that region was at its worst. At the same time the existence of the Reindeer and the Marmot point to a summer temperature considerably lower than that of the present.

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[1] The formation of peat within the channel of a river, upon soil constantly saturated, indicates a dry rather than a humid period. The frequent occurrence of floods, as M. Belgrand points out, would effectually prevent the accumulation of peat.

REVIEWS.

DER AUFBAU DER ERDE. By B. GUTENBERG. pp. viii + 168, with 22 figures and 62 tables. Berlin: Borntraeger, 1925.

DR. GUTENBERG is a well-known explorer of the inner earth who has made substantial contributions to the development of seismology during the last ten or twelve years. A book from his pen dealing with the structure of the earth from the standpoint of geophysics is therefore a welcome addition to the rising tide of German literature. The book does not so much present a particular point of view as provide in textbook form a competent summary of all the evidence so far collected and the hypotheses that have been based on it.

The first chapter gives a clear and authoritative account of the interpretation of earthquake records with special reference to the earth's interior. The form and density of the earth next receive attention, and Washington's recent work on the co-ordination of elevation and rock-density, and that of Williamson and Adams on the downward distribution of density and pressure are well summarized. Temperature distribution is considered with full appreciation of the importance of radioactivity. The treatment is historically satisfactory, but unfortunately it stops short at Joly's conception of the basaltic cycle of fusion and consolidation. This is merely hinted at in one brief sentence, as though Dr. Gutenberg, like some other geophysicists, had been afraid either to commit himself to a conjecture so daring or to criticize it adversely. However, radioactivity is clearly coming into its own as a geological agent, and American geologists can no longer have any excuse for ignoring it, as most of them have done, unaccountably, in the past.

After a brief account of polar variations and tides, rigidity and compressibility are dealt with at greater length, and here we find most of the recent researches of Adams and Williamson and Bridgman fully recognized. Various hypotheses of the structure of the crust are next considered, leading up to a short summary of the evidence for isostasy, and a very thorough discussion of the seismological data. The chapter on the composition of the earth, and the distribution of the elements within it, is based entirely on papers published since 1922 by Goldschmidt, Linck, the workers of the Carnegie Institution, and others. A number of different schemes have been suggested, the chief region of controversy being that lying between the crust and the core. The relative abundance of eclogite in the upper levels and of sulphides in the lower is a speculative subject that seems likely to provoke diverse opinions for many years. As to the state of aggregation of matter in the depths, Linck's ideas are favoured. According to that author the core is composed of simple atoms, and on passing outwards binary compounds and simple silicate molecules appear in turn, all the material being in an isotropic or " glassy " condition until the outer anisotropic zone of familiar crystallized minerals is reached.

The book concludes with an account of the structure of the atmosphere, a general summary for the earth as a whole, and an excellent bibliography. Naturally no final conclusions are advocated, for the whole vast subject is still in the stage where multiple working hypotheses are desirable. A great deal of widely scattered information is conveniently gathered together in a very compact form. Tables of data abound (for example, of elastic constants, thermal gradients, velocities of earthquake waves, elevations, and their distribution, and chemical composition) and competitive hypotheses are schematically displayed, so that even to one who reads German with difficulty the book is invaluable as a storehouse of facts and opinions, not mixed, but carefully distinguished. Those of us who have had to search a widespread literature for geophysical data will realize how great the need has been for a book of this kind. An adequate guide up to 1924 is now available to everyone, and Dr. Gutenberg's book therefore deserves a place in every geological library.

Arthur Holmes.

Catalogo Descriptivo de los Minerales de Muso. By R. Ll. Codazzi. Biblioteca del Museo Nacional, Bogotá, Republica de Colombia. pp. 25. Bogotá, 1925.

THE object of this very interesting little pamphlet, which is badly printed on the worst possible paper, is, as stated in the introduction, to describe the collection of minerals from the emerald mines of Muzo, exhibited in the National Museum at Bogotá. It begins with a very clear description of the physiography of the region, and passes on to a brief account of the geological formations. These comprise Quaternary, Tertiary, Cretaceous, and pre-Cretaceous rocks, with igneous intrusions. The pre-Cretaceous rocks consist of crystalline schists, phyllites, and quartzites, possibly pre-Cambrian. The descriptions of the later sediments are in some cases rendered obscure by the vagueness of the word " esquisto ", which is exactly equivalent to *schiste* and *Schiefer*. It is hardly necessary to enlarge further on this point, which is self-explanatory and a standing reproach to so many foreign languages.

The subdivisions of the Cretaceous are compared by the author with German sedimentary types (Pläner, Quader, Lettenkohle, and so on). This system is intensely folded.

The emerald mines are found in the middle division of the Cretaceous, the Villeta series, which consists of black and grey slates, calcareous shales, and black limestones with many fossils, especially ammonites and species of *Trigonia.*

The emeralds occur in veins which traverse the much-folded and faulted black slates. These veins consist principally of calcite, dolomite, pyrite, and quartz, some, however, being mainly composed of fluorite and quartz. The emeralds are embedded among crystals of quartz and calcite. There are drusy cavities, in which good crystals of fluorite, albite, apatite, and parisite are often found.

The minerals enumerated in the general list as occurring in the veins are emerald, parisite, albite, barytes, fuchsite, talc, pyrophyllite, allophane, quartz, calcite, aragonite, fluorite, apatite, gypsum, ankerite, siderite, pyrite, marcasite, limonite, and anthracite (? bitumen). Some of these are doubtless secondary, but it is an interesting assemblage.

Associated with the veins are two formations known to the miners as "cama" and "cenicero". It is difficult to make out what the last-named may be, as the usual meaning of cenicero is ash-bin, which is not very helpful from the geological point of view. The "cama" is described as a mass of large rhombohedral crystals of calcite with some clear quartz.

From this description, however, it seems clear that the emerald-bearing veins represent late-magmatic concentrates of pneumatolytic type in which beryllium is a dominant constituent. Whether these are related to the intrusive rocks of the neighbourhood, described as consisting chiefly of very recent porphyrites, remains an open question.

R. H. R.

Researches in Sedimentation in 1924. Report of the Committee on Sedimentation. By W. H. Twenhofel, Chairman, and Members of the Committee. pp. 78. Issued in mimeographed form by the National Research Council, Washington, D.C., 1925.

THE first thirty pages of this Report are occupied by statements of the researches on sedimentation now in progress in America, giving evidence of continued activity in this comparatively new branch of geology, especially among geological surveys. Mr. L. M. Neumann gives a summary of studies of sediments by oil companies, an important practical application of the subject, and Professor W. A. Tarr, as a result of his recent visit to European laboratories, reports on the researches there in progress; these are chiefly confined, so far as is known, to the British Isles, France, Italy, and Geneva. He singles out for special mention the work of Collet in Switzerland, Cayeux in France, and Artini in Italy. The rest of the report is largely occupied by special articles, too numerous to mention in detail, but of much value from different points of view. The Chairman gives an interesting account of the formation of oolites in his domestic hot water pipes. Many of the articles contain valuable bibliographies. It is announced that the Treatise on Sedimentation, arranged for by the Committee, is now approaching completion, and will probably appear early in 1926, as a volume of some 600 pages. A chart of standard colours for description of sediments, now in preparation, should be of great value, as hitherto there has been much vagueness in this branch of sedimentary petrography.

THE SLATES OF WALES. By F. J. NORTH, D.Sc., F.G.S. pp. 66, 8 plates and 7 text-figs. Published by the Museum and by the Press Board of the University of Wales. Cardiff, 1925. Price 6*d*.

THIS excellent little book is primarily a guide to the exhibit of slates in the National Museum of Wales, but in its pages Dr. North has not only given a summary of the theoretical and scientific views regarding slates and their formation, but also he has given us details of the history and practical working of Welsh slates and their use in commerce.

Geologists may not be willing to agree with Dr. North that all the slates of the Nantlle-Bethesda belt are of Lower Cambrian age; this, however, is a very minor point.

The guide ends with a full bibliography, collected from many scattered sources, regarding all aspects of slate, 53 references being to works or papers on Welsh slates.

CONGRÈS GEOLOGIQUE INTERNATIONAL. COMPTES RENDUS DE LA XIIIME SESSION. BELGIQUE, 1922. Premier et deuxiéme Fascicules. pp. 1197, Liége, Vaillant-Carmanne, 1925.

LIVRET-GUIDE DES EXCURSIONS EN BELGIQUE. XIIIme Congr. Géol. Internat., 1922. Liége, 1925.

THE two large first-named volumes contain the official reports of the meetings of the Congress and a large proportion of the papers read: the remaining part has been somewhat delayed in publication, but will shortly appear. The principal subjects submitted for discussion at the Congress were as follows: the tectonics of the Hercynian fold-system; the geology of the Carboniferous period; the relations between folded and sunken zones of the crust; the geology of Africa; the geological and palæontological relations of the northern and southern hemispheres; the tectonics of Asia; the lithology of the sedimentary rocks; oil-geology.

The reports contain the text of a large number of memoirs on most of these subjects, while the rest will doubtless appear in the third part; it is much to be hoped that this will also include an efficient index. The first part contains a most important memoir by M. Émile Argand on the tectonics of Asia: this runs to 200 pages, and is frankly very tough reading. It includes besides Asia a good deal on the tectonics of Europe and of other regions, and is well worthy of most careful study. It is impossible here, however, to attempt even a brief summary of its contents. We may note, however, that the translation into English of some of the author's technical terms is a matter requiring most careful consideration, as this memoir is likely to remain for long a classic in its own line. It is intended largely to illustrate a great map of Asia, exhibited at the Congress.

As is only natural Hercynian tectonics and Carboniferous geology occupy much space, owing to their special application to Belgium, and both the detailed papers here printed and the excursion guides contain much matter of value to English stratigraphers. Recent researches on the great overthrusts of the Belgian coal-fields have led to most important and remarkable results, especially in connexion with the "window" of Theux, and the relations of the Faille du Midi, the Crête du Condroz and the Eifel fault.

At some future date we may perhaps hope to notice individually some of the notable contributions to these volumes. At present it must suffice to offer hearty felicitations to the officers of the Congress, and especially to the Secretary, M. Armand Renier, on the success that has attended the deliberations of the Congress in general and the publication of these reports and guides in particular.

R. H. R.

A PIONEER OF PREHISTORY. By KEVIN CLARK, O.P., F.G.S., Blackfriars. vol. vi, pp. 603–613, 640–648, 726–738, October–December, 1925. Oxford: Basil Blackwell.

IN this series of three articles, Father Kevin Clark, of the Dominican Order, has given a most interesting sketch of the work of Father John MacEnery, of Torquay (1796–1841), who was so largely responsible for the investigation of the epoch-making deposits of Kent's Cavern. It was his work that first definitely established the co-existence of man with extinct animals in Britain, and paved the way, in spite of much opposition from geological and theological orthodoxy as then understood, for the recognition of the work of Boucher de Perthes in France, and for the development of human palæontology along modern lines. In spite of ill-health, poverty and discouragement, Father MacEnery persisted in his work, and his careful and painstaking researches were carefully recorded in a voluminous manuscript, long lost, but recovered by a fortunate accident, and now carefully preserved in the Torquay Museum. It is deplorable that from want of support from the scientific world of the day, it was found impossible to publish this manuscript, but at any rate the value of the work done by its author is now fully recognized, and his name will go down to posterity as one of the foremost pioneers of this important branch of science. These articles should be read by all who are interested in the subject, as they give in an attractive and readable form the history of this interesting and most important episode in the development of British geology and of the science of prehistoric anthropology.

GEOLOGICAL SURVEY OF NIGERIA. Occasional Paper No. 1: BROWN COAL IN NIGERIA. By R. C. WILSON. pp. 21, map. 1925. Published by the Nigerian Government.

THIS paper is concerned more with the economic utilization of the Lignites or Brown Coals than with the geology of the districts in which they occur.

Numerous processes for dealing with this material, by briquetting, by carbonization, or when pulverized, are dealt with and analyses given. The latter include the results of an Engler distillation of the oil obtained from a bulk sample of the Nigerian fuel.

It is satisfactory to learn that briquettes manufactured from Okpanam lignite are superior to the average German article. Without the Enugu coal, this lignite would form a factor of great importance in the development of the Protectorate; with it, there lies a reserve of fuel of enormous tonnage, of easy accessibility, and in no way inferior to coals already successfully exploited.

J. P.

AN INTRODUCTION TO PHYSICAL GEOLOGY. By W. J. MILLER. pp. xvi and 435, with 351 figures. London: Chapman & Hall, 1925. Price 13*s*. 6*d*. net.

THIS introduction to physical geology by Professor Miller is a companion volume to his *Introduction to Historical Geology*. Although written with special reference to North America, it should not on this account be disregarded by British students, for they will find in it a clear and graphic presentation of the subject, well illustrated by abundant maps, diagrams, and photographic reproductions.

After a brief introductory chapter there follows a somewhat detailed account of the materials of the earth's crust, the author claiming with some justification that this early treatment is the logical arrangement being "fundamental to all that follows". The arrangement of the rest of the book is quite conventional, but includes particularly interesting and well-written chapters on structures, streams, and glaciers. It is, however, somewhat surprising to find the final chapter on economic geology the least satisfactory in the whole book, the treatment of ore deposits being unsystematic with unnecessary space devoted to production figures.

One or two minor blemishes occur in the text. Petrographers, for example, may well look askance at a classification of igneous rocks which omits olivine from the chief constituent minerals of peridotites, while some of the abundant photographic reproductions are too small to be of much service.

These few flaws do not, however, detract from the value of the book as a whole, and it may be cordially recommended to all English-speaking students.

Not the least attractive feature is its price which, in view of the excellent binding, print, and paper, is remarkably reasonable.

THE GEOLOGY OF THE THAMES VALLEY NEAR GORING, as illustrated by the Model in the Museum of Practical Geology. By Sir A. STRAHAN, K.B.E., F.R.S. iv + 22 with 2 plates. Mem. Geol. Surv., 1924. Price 6*d*.

NOW that the public has regained access to the Museum of Practical Geology in Jermyn Street, it may be well to note the publication of the short guide to this model, which illustrates the geology of one of the most picturesque parts of the Thames Valley. A brief account of the solid geology and topography is given, where the Goring Gap is explained as an example of superimposed drainage originally initiated in the Tertiary covering as a simple consequent river located in its present site by the synclinal cross folding of the London basin.

Several pages of text and Plate II are devoted to the underground water levels in the Chalk, but it is unfortunate that the records are so scanty in the northern part of the area.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

"The Submerged Forest at the Mouth of the River Char, and the History of that River." By W. D. Lang, M.A., Sc.D., F.G.S., F.Z.S.

A temporary exposure of the submerged forest at the mouth of the Char is described, and the general history of the river discussed.

The map shows how the River Char, its tributaries, and the neighbouring streams, flow at first in a general S.S.E. direction, and then, at some point in their course, turn abruptly S.W. It is held that the earlier reaches are the relics of ancestral parallel streams consequent upon a post-Eocene uplift with a general E.-and-W. axis; and that the later reaches are subsequent affluents, which, because they flow along the line of strike of the Lias clays, have developed faster than the parent consequent streams; and, having cut their beds down to the clays first in the west, have successively beheaded those consequent streams lying to the east of them. Thus, originally there were five consequent streams, namely, from west to east, the ancestors of (1) The Buddel; (2) the Wootton

Stream, continued in a S.S.E direction from Newlands Bridge, and over what is now the shoulder of Stonebarrow Hill; (3) the Cards Mill Brook, continued over the gap at Morecombelake into the upper reaches of St. Gabriel's Water, which, in turn, continued in a S.S.E direction over the gap between Golden Cap and Langdon Hill; (4) Marshwood Brook and Middle Brook, continued in a S.S.E direction over a gap under Ryall, into the upper reaches of the Winniford, and thence over a gap S.W. of Thorncombe Beacon; (5) the Char brook, continued in a S.S.E. direction over a gap near Broad Oak, and into the River Simene. Thus the Char is seen to be a composite river, made up of affluents of the first four of the consequent streams mentioned above, and of the ancestral Simene.

St. Gabriel's Water is similarly composed of an original consequent beheaded by an affluent of the ancestral Wootton Stream; and the Winniford, or Chid, of an original consequent beheaded by an affluent of the ancestral Card's Mill—St. Gabriel's Stream. Thus the sharp elbow-like turns in each of these streams are accounted for.

"Some Phases in the Structural Evolution of the London Basin." By S. W. Wooldridge, M.Sc., F.G.S.

In 1923 a paper was published in which the various minor structural elements of the London Basin were described. (*Proc. Geol. Assoc.*, vol. 34 (1923), p. 175.) The communication now laid before the Association is a sequel to the former paper and seeks to trace the development in time of the minor structures and of the main syncline to which they are subsidiary. This has been done by comparing a series of maps showing the regional variations in thickness and lithology of the several Eocene formations. The effects of contemporaneous warping along lines closely coincident with existing structures are clearly legible in the beds, and it is hence concluded that many of the faults and folds now traceable in the Basin date back in some form to Eocene, or earlier times.

Particular attention is drawn:—

(*a*) To an axis of persistent instability running E.–W. along the line of the present Lower Thames. It seems probable that this indicates the position of one of the major Armorican flexures in the Palaeozoic floor beneath London: possibly it is the eastern continuation of the "Cardiff-Cowbridge" line.

(*b*) To the importance of Charnian movement.

(*c*) To the prevalence of N.–S. structural lines of a general monoclinal nature, whose influence is traceable in the existing topography, and also in the constitution and thickness of the Eocene beds, and which may plausibly be correlated with faults in the Palaeozoic floor.

The results of the investigation afford an example of the delicate relation subsisting between earth-movement and sedimentation and may be compared with those recently obtained by other workers in Jurassic, Carboniferous, and Silurian rocks.

EDINBURGH GEOLOGICAL SOCIETY.

21*st October*, 1925.

"Soil Survey Work in America." By J. O. Veatch, Research Associate, Soils, Michigan Agricultural Experiment Station, East Lansing, Michigan, U.S.A.

Remarks upon the history of soil classification were presented, and the present concepts and methods were briefly described.

The chief matter of interest to geologists is the opinion that the purely geologic conception of soils must undergo considerable modification, or perhaps be largely replaced by a new taxonomic scheme, if we are to develop a natural scientific classification of soils and one capable of universal application.

(1) The concept of the Russian pedologist, K. Glinka, that differences in climate and moisture conditions under which soil has developed are the primary causes of differences in soils studied from a broad view-point, and (2) the principle insisted upon by Dr. C. F. Marbut of the United States Bureau of Soils, that the classification must be based upon the intrinsic differences of the soils themselves, and not directly upon associated and environmental things as geology, vegetation, or agriculture, were presented and upheld.

The chief reason why the divisions of a geologic map may not be taken as coinciding, in general, with the distribution of soil types or groups is that two very important factors may be thereby ignored: (1) the age of the soil and the completeness of the soil profile, (2) the drainage or moisture conditions under which the soil has developed. It is pointed out that soil types may bear a very close relation to the purely lithologic character of rocks, but not necessarily to formations or to divisions based upon age, fossil life and origin. Further, the geologic map does not provide a means of correlating soils in widely separated areas.

A knowledge of geology, however, is an essential part of the equipment of the pedologist, and a thorough understanding of the geologic relationships and a detailed geologic map will greatly expedite the mapping of soils. A tentative taxonomic scheme for soils was presented.

18*th November*, 1925.

1. "Volcanic Vents on the Shore East of Tantallon Castle, at Seacliff and Whitberry Point." By T. Cuthbert Day, F.C.S., F.R.S.E.

The author, in this paper, continues his observations on the ancient volcanic orifices to be seen on the shore east of North Berwick. The late Sir Archibald Geikie, in the Memoir of the Geological Survey for East Lothian for 1866, states, with regard to the rocks on the shore at Seacliff, that: "This part of the shore is unquestionably the site of one or more volcanic orifices. The circular patch of breccia below Seacliff House, breaking through the sandstones and marls is a *true neck.*" Also, when describing the disturbed rocks at Whitberry Point, with their intrusion of basalt, he designates the section "a felstone neck". These statements have not been repeated in the revised Memoir of the Geological Survey for East Lothian for 1910; but the author, after a careful inspection of the ground, is convinced that Sir Archibald Geikie's judgment is amply confirmed. At Seacliff, three-quarters of a mile east of Tantallon Castle, two volcanic vents have been recognized: (1) the Seacliff Vent, on the shore below Seacliff House; and (2) the Car Vent, comprising the northern part of the Car Rocks, associated with which, in the sandstones outside the vent, is a large explosion fissure filled with volcanic ash. At Whitberry Point, three and a half miles south-east of Tantallon Castle, another volcanic vent exists, the central part of which is occupied by an intrusion of basalt, a well-known feature of which is St. Baldred's Cradle.

2. "On Chlorophaeite." By Dr. R. Campbell, F.R.S.E., and James Lunn, B.Sc.

The mineral chlorophaeite has been found to occur abundantly in the tholeiites of Dalmahoy and Kaimes Hills, near Edinburgh. An account was given of the chemical and physical characters of the mineral, which is colloidal in nature. It exhibits striking colour changes on exposure, passing from pale to dark green in fifteen minutes, and after ninety minutes becoming jet black. Experiments have shown that the change is due to oxidation.

YORKSHIRE GEOLOGICAL SOCIETY.

Annual Meeting, 28*th November*, 1925.—Professor E. J. Garwood (Presidential Address): "Some Problems in River Development."

In 1914, at Professor Kendall's instigation, the Society decided to undertake the investigation of the rivers of Yorkshire. Work was begun on the Washburn, a tributary of the Wharfe, but was abandoned owing to the War and had not since been continued. He expressed the hope that the work might now be carried on, and in this connexion he proposed to call attention to certain problems in river development which had not always received the attention they deserved in this country. He alluded to the interesting relation which so often obtains between a river and its tributaries, "Why do the tributaries so frequently enter the main stream at the concave bank of the meanders?" In attempting to answer this question it would be necessary to consider the various factors which might influence a river in departing from a constant direction in any part of its course. The subject might be divided under two heads, namely—*Original Curves* and *Subsequent Meanders.* Original curves may be developed in solid rock by the influence of joints as in the case of the Cheddar Gorge or might be superimposed in an overlying deposit such as drift, a good case being that of the Till below Etal in Northumberland.

Then there was the question of the effect of the earth's rotation known as Baer's law. How far could this be proved to exert an influence in diverting rivers to the right in the northern hemisphere? Other points considered were:—

The results of regional tilt; the effect of wind and the differential erosion of the banks by prevailing rain-bearing winds as suggested by Fabre in the case of the rivers flowing over the plateau of Lannemezan at the foot of the Pyrenees.

Further points considered were the evidence of lateral migration as shown by "cut-offs"; the position of maximum velocity in a meander system; and the tendency of the meander system to migrate down the valley. Other features discussed were "incised" and "intrenched" meanders, and "underfit" rivers.

The address concluded with a discussion of the original problem: "Do the meanders of the river deflect the tributaries so as to force them to enter at the concave banks or do the tributaries exert an influence in deflecting the course of the river?"

Though realizing that further investigation was required before the question could be satisfactorily answered, it was suggested that while accepting Professor W. M. Davis' view that the general migration of the meanders down the valley may tend to cause the tributaries to enter at the concave banks—cases could be cited where the tributaries appeared to have exerted a marked influence in determining the meanders. The address was illustrated by maps and diagrams in explanation of the various examples quoted.

CORRESPONDENCE.

THE BASE OF THE MILLSTONE GRIT NEAR HAVERFORDWEST.

Sir,—In connexion with the horizon of the Millstone Grit at Haroldston St. Issels, and the problems of the relations of the Millstone Grit to the Lower Carboniferous in South Wales, referred to by Professor O. T. Jones in your December number (p. 558), it may be of interest to state that a student here, Mr. R. O. Jones, B.Sc., has for some time been investigating the Millstone Grit faunas of South Wales. A few of his goniatites have been submitted to Mr. W. S. Bisat, and the evidence already obtained proves the existence of the overlap suggested by Professor Jones. In Carmarthenshire and Glamorgan, goniatites collected near the base of the Millstone Grit indicate the presence of zones below that of *Reticuloceras reticulatum*, which occurs at the base of the series at Haroldston. Apparently the basal beds are of different dates in various parts of Glamorgan.

Mr. R. O. Jones' results will be published in due course, but in view of Professor Jones' letter it appears desirable to record these conclusions now.

It is hoped during the next few months to carry out some digging in the basal Millstone Grit near Bishopston, Gower, where the succession is presumably more complete than in many parts of South Wales.

A. E. TRUEMAN.

ANNOUNCEMENTS AND INQUIRIES.

A report by Dr. W. H. Collins on the geology of the north shore of Lake Huron has been published by the Geological Survey of Canada. It presents the results of a detailed examination of the lithological, structural, and stratigraphic features of the Pre-Cambrian rocks underlying the area and of the age relations of the different systems. The section of country studied includes the type Huronian area and the report will consequently prove of great interest to students of Pre-Cambrian geology. Descriptions are also given of the deposits of gold, copper, and other economic minerals. Copies of this report may be had on application to the Director, Geological Survey, Ottawa.

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The results of an attempt to fix the time of the retreat of the last ice-sheet from Eastern Canada are presented in a report by Ernst Antevs recently published by the Geological Survey of Canada. The method employed is one that has been used in north-western Europe. It consists in counting and correlating the annual layers of sediments deposited in lakes lying at the edge of the ice-sheet. An interesting piece of work is that which shows that the retreat of the glacier from the mouth of Montreal river on Lake Timiskaming northward to Englehart was made in 600 years. Interesting notes are also given on the large lakes that occupied the basins of the Great Lakes during glacial times and on the flooding of the St. Lawrence and Ottawa valleys by the sea when the ice-dam holding it back was removed. A charge of twenty-five cents is made for this publication. It can be had by applying to the Director of the Geological Survey, Ottawa.